Final Report

OGO-I VLF EXPERIMENT A-17 DIGITAL DATA PROCESSING SYSTEM

By: B. P. FICKLIN, M. E. MILLS, W. E. BLAIR, N. D. SCHLOSSER, J. H. WENSLEY, W. H. ZWISLER

Prepared for:

STANFORD UNIVERSITY
STANFORD, CALIFORNIA

SUBCONTRACT S-142 UNDER
CONTRACT NAS5-2131

STANFORD RESEARCH INSTITUTE

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ABSTRACT

This report is concerned with the digital data processing technique of the Stanford University/Stanford Research Institute VLF radio noise and propagation experiment (A-17) aboard the OGO-I satellite. Descriptions, operational procedures, and details of the instrument and satellite are given as required for understanding of the data processing system. The NASA/GSFC (Goddard Space Flight Center) data acquisition, decommutation, and processing systems are briefly described. The input, output, and operation of the four-phase SRI data-processing system are presented in detail. The computer display system and 16-mm cine film presentation are also described, and examples are shown.

On more than 2×10^5 frames of film, 2×10^8 experimental digital data bits of information covering 99 satellite revolutions have been plotted and stored. This accumulation of data represents more than 10^5 bits of information per frame and was computer processed at approximately three frames per second. This cine film technique provides capability for:

(1) Significant data compacting

(2) Quick scanning of data

(3) Discrimination between signals and interference

(4) Recognition of unique data characteristics

(5) Simultaneous data comparison.

The application of this technique is considered the final phase of the data processing and the initial phase of the data analysis.

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ABBREVIATIONS

ADHA	Analog data-handling assembly
BCD	Binary-coded decimal
BCO	Binary-coded octal
b/s	Bits per second
CAOR	Collated card-orbit tape
CRT	Cathode-ray tube
DDHA	Digital data-handling assembly
DHE	Data-handling equipment
EAM	Electric accounting machine
EOGO	Eccentric Orbiting Geophysical Observatory
EP-5	Experiment Package No. 5
ESSA	Environmental Science Services Administration (Boulder, Colorado)
FH	Electron gyrofrequency
FHO	Minimum electron gyrofrequency along the magnetic field line through the satellite
FM/PM	Frequency-modulated/phase-modulated
GEI	Geocentric equatorial inertial
GEIC	Geocentric equatorial inertial coordinates
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
GSE	Geocentric solar ecliptic
GSM	Geocentric solar magnetic
HBR	High bit rate
IC	Impulse command
kb/s	Kilobits per second
LBR	Low bit rate
LO	Local oscillator
MBR	Medium bit rate
MC	Main commutator
NASA	National Aeronautics and Space Administration
OGO	Orbiting Geophysical Observatory

OGO CC	Orbiting Geophysical Observatory Operations Control Center
OPEP	Orbital-plane experiment package
PC	Power command
PCM/PM	Pulse code modulation/phase modulation
POD	Project Operations Director
POGO	Polar Orbiting Geophysical Observatory
SBR	Stored bit rate
SC	Subcommutator
SD	Serial Decimal
SEP angle	Sun-earth-probe (satellite) angle
SP	Special-Purpose (analog)
SP TLM	Special-Purpose telemetry
STADAN	Space Telemetry and Data Acquisition Network
SRI	Stanford Research Institute, Menlo Park, California
SU	Stanford University, Stanford, California
TOD Tape	Time-ordered data tape
VCO	Voltage-controlled oscillator
WB	Wideband (digital)
WBT	Wideband telemetry

ACKNOWLEDGEMENTS

Several people from various organizations have contributed directly or indirectly to this project during the past five years. Without their assistance and suggestions, many of the results obtained on this project could not have been accomplished.

The authors gratefully acknowledge the following contributors to the OGO digital data processing program generally and to this project specifically:

L. H. Rorden and L. E. Orsak, now of Develco, Inc., who when members of the staff of Stanford Research Institute, together with the authors, designed and developed the OGO-I Experiment A-17 instrument and conceived the computer processing technique and a cine film display of the data;

R. A. Helliwell, principal investigator of Experiment A-17 at Stanford University, under whose supervision and support the project was directed and successfully completed;

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1. INTRODUCTION

The first Orbiting Geophysical Observatory (OGO-I) launched in September 1964 is one of a series of large satellites to carry a variety of scientific experiments for making simultaneous observations of geophysical phenomena in the ionosphere and magnetosphere. The primary objective of the OGO series is to obtain a better understanding of the earth-sun geophysical relationships and the earth's atmosphere. On OGO-I twenty diversified experiments were carried, to observe cosmic rays, γ rays, X rays, plasma constituents, trapped radiation, radio propagation and noise, the earth's magnetic field, interplanetary dust particles, Lyman-α scattering, and the gegenschein.[1*] This report describes the SRI processing of the Wideband (digital) data gathered aboard OGO-I by the joint Stanford University/Stanford Research Institute (SU/SRI) VLF Experiment A-17 for study of radio noise and propagation. The results of the data analysis will be reported separately in subsequent papers and reports. The Special-Purpose (analog) data were processed by Stanford University. The goals of the SU/SRI VLF experiment have been to compile a comprehensive survey of VLF noise of natural origin and thus to extend the understanding of VLF propagation in the environment of the OGO-I satellite.

The OGO-I satellite has many modes of operation to handle various types of data and to provide various data sampling rates. One of the remarkable capabilities of this satellite is the large quantity of data that it can return to ground during its lifetime. It can transmit digital data in real time at 1,000, 8,000, or 64,000 binary bits per second (b/s) and simultaneously transmit analog data with a bandwidth of 100 kHz. Operating continuously at 1 kb/s for one year, the spacecraft would transmit 3×10^{10} bits of data. Experiment A-17 gets about

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*References are listed at the end of the report.

6 percent of all the digital data collected; at the 1-kb/s data rate, it would get 2×10^9 bits of information in one year.

Since OGO-I was to carry the first VLF receiver to altitudes greater than 3,000 km and even into interplanetary space, it was desirable that every bit of data received be scrutinized. A process allowing data viewing at a rate of at least two orders of magnitude faster than the rate at which the data were taken was sought. Rapid viewing or scanning of the data was also necessary, to determine the most significant or most common events from large samples of data contaminated with interference signals. Clearly, the handling, processing, and analysis of such an overwhelming quantity of data required a new and original approach.

In 1963 SRI launched two Aerobee rockets to obtain scientific data and to test the design concepts and operations of the OGO-I VLF instrumentation. The results from these Aerobee rockets have been reported.[2] The data received from the instruments on board the Aerobees were processed by photographing each sweep frame of strip-chart data onto 16-mm cine film. This method provides both rapid viewing of large quantities of data and compact, convenient storage. Other advantages of photographing the data are apparent from viewing the completed films: The capability for discrimination between signals and coherent interference has been improved considerably over other techniques, and varying the speed of projection causes an apparent change in the integration time constants.

From the experience gained with the Aerobee films, it was decided that the principal emphasis of the OGO digital data reduction effort should be put on producing a film display of all the digital data from the satellite. With this film display, 768 data points or 10^5 bits of information are displayed and stored on one frame of 16-mm film. Each data point is computed from a 9-bit data word. Consequently, at 16 frames per second (normal projection speed), one can scan 4×10^7 data points or 4×10^9 bits of information in 1 hour.

The quantity of OGO-I data reduced and stored on film to date is on the order of 10^8 data points or 2×10^{10} bits of information and includes every bit of data from Experiment A-17 through Revolution 99. After Revolution 99, the data reduction process was stopped to allow time for as much data analysis as possible with the remaining contract time and funds. Data are still being transmitted from OGO-I and data processing and analysis should be resumed.

2. DESCRIPTION OF EXPERIMENT A-17

2.1 Application

The joint SU/SRI VLF experiment[3] aboard the OGO-I satellite was intended not only to verify ground observation by direct measurement in the magnetosphere but also to explore the VLF electromagnetic environment beyond the magnetosphere. The instrumentation for this experiment was designed to accomplish the following three main scientific goals:

(1) To compile a comprehensive survey of VLF noise of natural origin found within the region of the orbit. The noise phenomena may be classified into the following categories:

 (a) terrestrial noise produced below a height of 70 km, such as atmospherics due to lightning;

 (b) noise generated within the earth's ionosphere and magnetosphere, such as VLF emissions produced by charged particles trapped in the earth's magnetic field; and

 (c) cosmic noise of extraterrestrial origin, such as solar and planetary noise.

 This survey is expected to be instrumental in determining the sources of various VLF phenomena observed on the ground and in other satellite and rocket experiments.

(2) To extend the understanding of VLF propagation in the ionosphere. This understanding should, in turn, increase our knowledge of the composition of the upper atmosphere, since the propagation of VLF waves is extremely sensitive to the low levels of ionization and magnetic field found there. Both natural and artificial sources have been used in propagation measurements, by employing techniques developed at SRI in previous rocket and satellite experiments.

(3) To compile engineering information that will improve the design of instrumentation for subsequent experiments, including evaluations of sensitivity, frequency range, resolution, dynamic range, stability, etc., to determine desirable modifications to these parameters.

Since the measurements undertaken by the OGO-I VLF receiver were exploratory in nature, the receiver was designed to provide a wide range of measurement capability and to have considerable versatility. The design includes wide frequency coverage (0.2-to-100-kHz contigous narrow-band measurements and 0.2-to-12.5-kHz broadband measurements), large dynamic range (approximately 80 dB), both sweep- and fixed-frequency operation of the narrow-band receivers, and capability for making relative phase measurements on ground transmitters. To meet these goals, significant development of improved receiver circuitry suitable for reliable satellite operation was necessary. The receiver that was developed bettered the original requirements of weight, size, and power; made efficient use of satellite data capability and ground commands; and yet provided VLF measurement capability not previously obtained.

2.2 Functional Description

The OGO-I VLF receiver consists of two major parts: an antenna with a preamplifier at the end of a long boom (EP-5) and the receiver electronics package located in the satellite main body.

The antenna is a torus, 2.9m in diameter with a 7.6-cm-diameter cross section, fabricated from aluminum-Mylar laminate in the form of an inflatable tube (see Fig. 2.1). This antenna was designed and built by the Antennas and Microwave Department of Lockheed Missiles and Space Company under subcontract to Stanford University. The deflated antenna was stowed in a small space during launch and was inflated in orbit by ground command after the long boom had been deployed. The loop antenna was connected to the preamplifier terminals by two wires, which also formed a small loop with approximately $0.1 m^2$ of included area; this loop served as a backup for the large loop in the event that it could not be deployed.

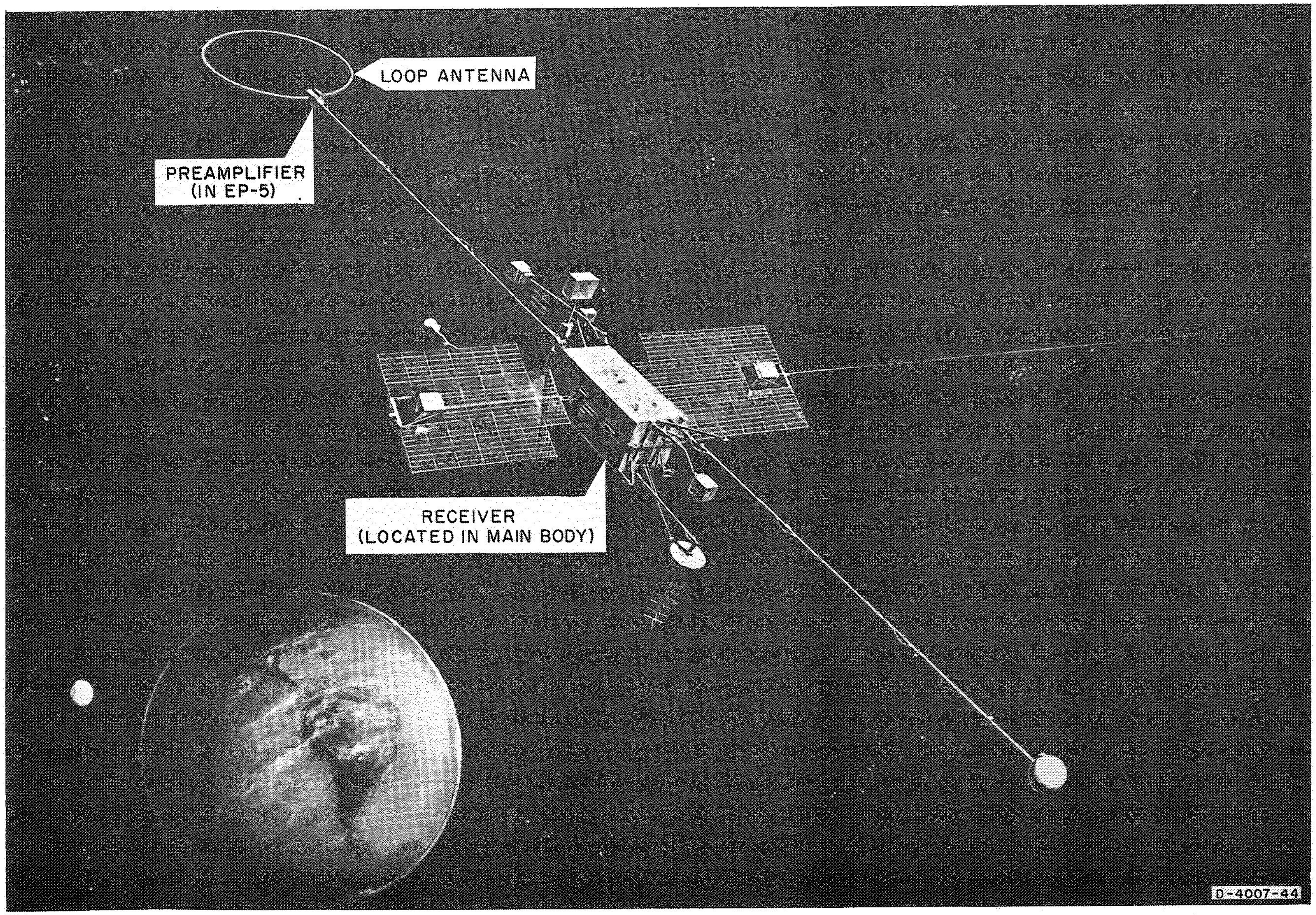


FIG. 2.1 OGO-I SATELLITE — ARTIST'S CONCEPTION

The preamplifier (Fig. 2.2) is a broadband, low-noise amplifier covering the frequency range 0.2 to 100 kHz, with noise temperature of approximately 50°K. The matching network between antenna and preamplifier includes a transformer to match the antenna impedance to the amplifier and to provide circuits for injecting a calibrate current in shunt with the antenna and a calibrate voltage in series with the antenna. These injections provide calibration of the receiver and are also used to measure the antenna impedance. Signal amplification is provided by the preamplifier so that interference signals picked up in the preamplifier output cables and thermal noise in the following circuits are negligible compared with the interference signals received directly by the antenna and the thermal noise of the preamplifier input circuit.

The receiver (Fig. 2.3) consists of three narrow-band receivers simultaneously covering the bands 0.2 to 1.6 kHz, 1.6 to 12.5 kHz, and 12.5 to 100 kHz, in 256 equal frequency steps. In addition, a broadband receiver gives the broadband spectrum and the average amplitude of signals in the 0.3-to-12.5-kHz range. Various modes for operating these receivers are provided by a memory operating from ground command. These modes include, in some combination, the following:

(1) automatic stepping of the narrow-band receivers in synchronism with the spacecraft digital data system, with each receiver output sampled by the Wideband telemetry system;

(2) stepping of the narrow-band receivers by ground command to any desired signal, with each receiver output sampled by the Wideband telemetry system and analog data on the amplitude and relative phase of the 12.5-to-100-kHz narrow-band receiver signal telemetered by the Special-Purpose telemetry system;

(3) average amplitude, with bandwidth of approximately 300 Hz and the broadband spectrum of the broadband receiver (0.3-to-12.5-kHz) signal telemetered on the Special Purpose system; and

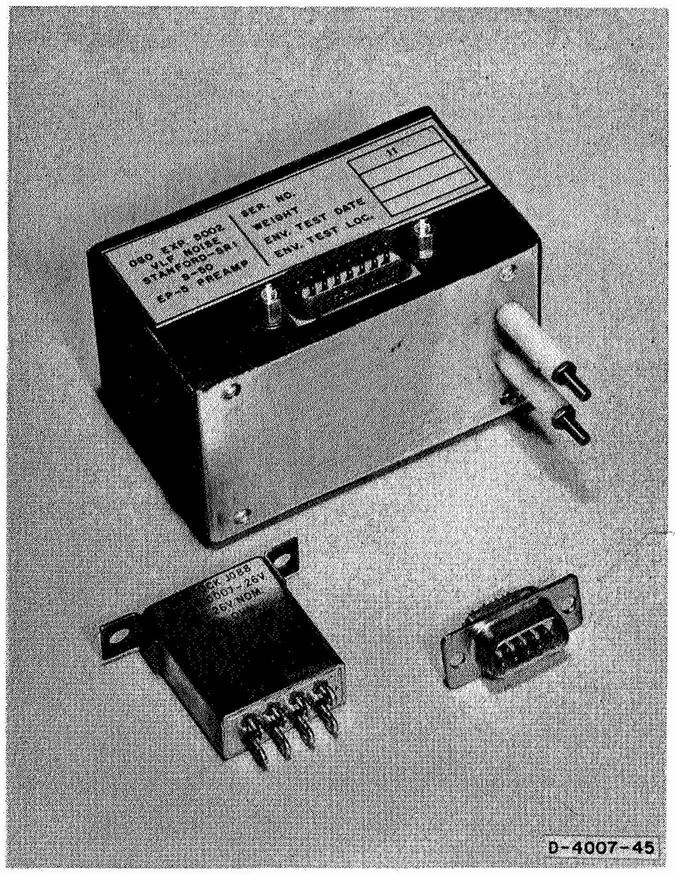


FIG. 2.2 EXPERIMENT A-17 PREAMPLIFIER ASSEMBLY

FIG. 2.3 EXPERIMENT A-17 RECEIVER ASSEMBLY

(4) injection of a combination of current and voltage calibrate signals into the antenna circuit every sixteenth frequency sweep of the narrow-band receivers.

The narrow-band and broadband receiver amplitude outputs are logarithmic functions of input signal, with a 20-dB range of output voltage representing signals from approximately receiver threshold to 80 dB above receiver threshold.

2.3 Instrument Calibrations

Several calibrations of the Experiment A-17 instrument were necessary in order to convert values of receiver output voltages into values of magnetic flux density. The calibration curves for each receiver are given in this section. All instrument responses were taken by using a dummy antenna, which is an accurate antenna equivalent. The loop antenna was considered fully inflated for the purpose of computing receiver sensitivities (expressed in decibels with respect to 1 gamma rms of magnetic flux density). Calibrations of the narrow-band receivers were made near the upper edge of each band, at 1.60, 12.7, and 90.0 kHz.

Since the three sweep-frequency receivers can receive signals from 0.2 to 100.0 kHz, the antenna preamplifier, located at the base of the antenna on EP-5, must have a reasonably smooth and stable frequency response over this band. The magnetic flux density, B, measured by the antenna is given by the following expression:

$$B = V/\omega A_e \quad , \tag{2.1}$$

where

V = rms antenna output and preamplifier input signal voltage
$\omega = 2\pi f$ = radian signal frequency
$A_e (\approx \pi R^2)$ = electrical effective area of loop
R = average loop radius.

The preamplifier has a constant voltage gain, and the input voltage increases with increasing frequency if the flux density is constant.

The response shown in Fig. 2.4 varies approximately as f for $0.2 < f < 100$ kHz.

The sweep-frequency receiver output, V, is logarithmically related to B in decibels with respect to 1 gamma (10^{-5} gauss, 10^{-9} tesla, or 10^{-9} Wb/m^2). The output for a given frequency is approximately linear on a logarithmic scale in Band 1 for $-75 < B < 0$ dB (as shown in Fig. 2.5), in Band 2 for $-95 < B < -20$ dB (as shown in Fig. 2.6), and in Band 3 for $-105 < B < -40$ dB (as shown in Fig. 2.7). The calibration in Band 3 for $B < 100$ dB could not be determined on the spacecraft but was measured in the laboratory prior to spacecraft installation (as shown by the dashed line in Fig. 2.7).

The broadband receiver, whose input is the output of the low-pass filter of the Band 2 sweep-frequency receiver, is sensitive to signals in the frequency range $0.3 < f < 12.5$ kHz. This is a logarithmic receiver, with an 80-dB dynamic range, whose amplitude output is the input to a voltage-controlled oscillator (VCO). The filtered output of the VCO, is, in turn, one input to the spacecraft Special-Purpose telemetry system. The calibration of this VCO for six frequencies in Band 2 is shown in Fig. 2.8. The VCO frequencies of synchronization and calibration pulses are indicated with arrows.

The same VCO can be used to convert the amplitude of either the Band 3 receiver or the broadband receiver to an FM subcarrier to apply to the Special-Purpose telemetry system. The Special-Purpose telemetry transmitter is phase modulated so that an FM/PM system results. The VCO is an emitter-coupled multivibrator that varies with frequency $27.75 < f < 32.25$ kHz as the input (antenna output) signal varies as $-120 < B < -30$ dB, if the Band 3 amplitude is used as an input. The VCO calibration is shown in Fig. 2.9 for an input signal frequency of 90 kHz.

The temperature of the antenna on the OGO-I EP-5 boom was monitored prior to inflation to determine whether it was within safe limits. The linear output varies over the telemetry range of $0 < V < 5V$, corresponding to a temperature range of $-80 < T < +160°C$, as shown in Fig. 2.10.

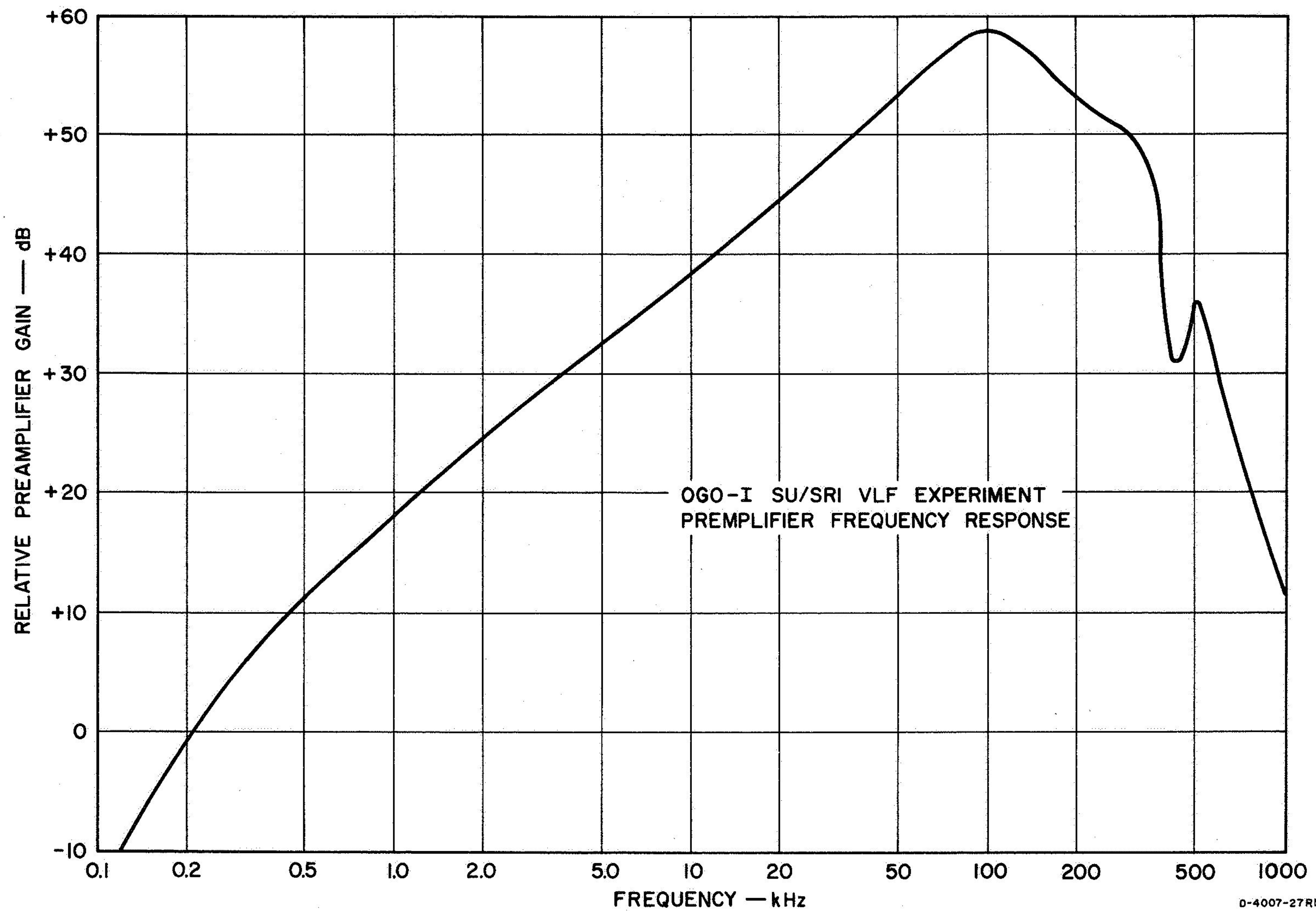


FIG. 2.4 FREQUENCY RESPONSE CURVE OF PREAMPLIFIER

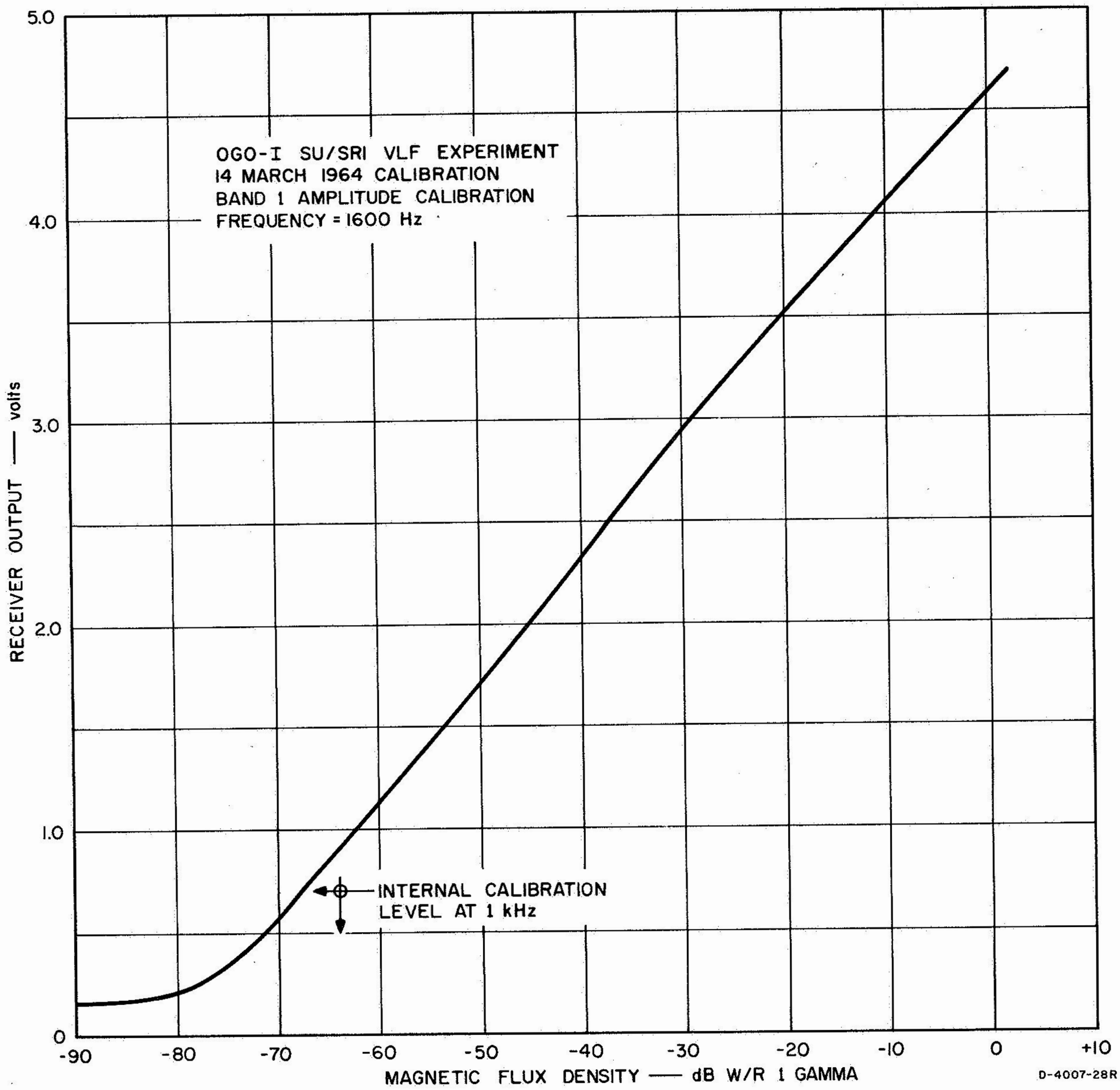


FIG. 2.5 BAND 1 CALIBRATION CURVE

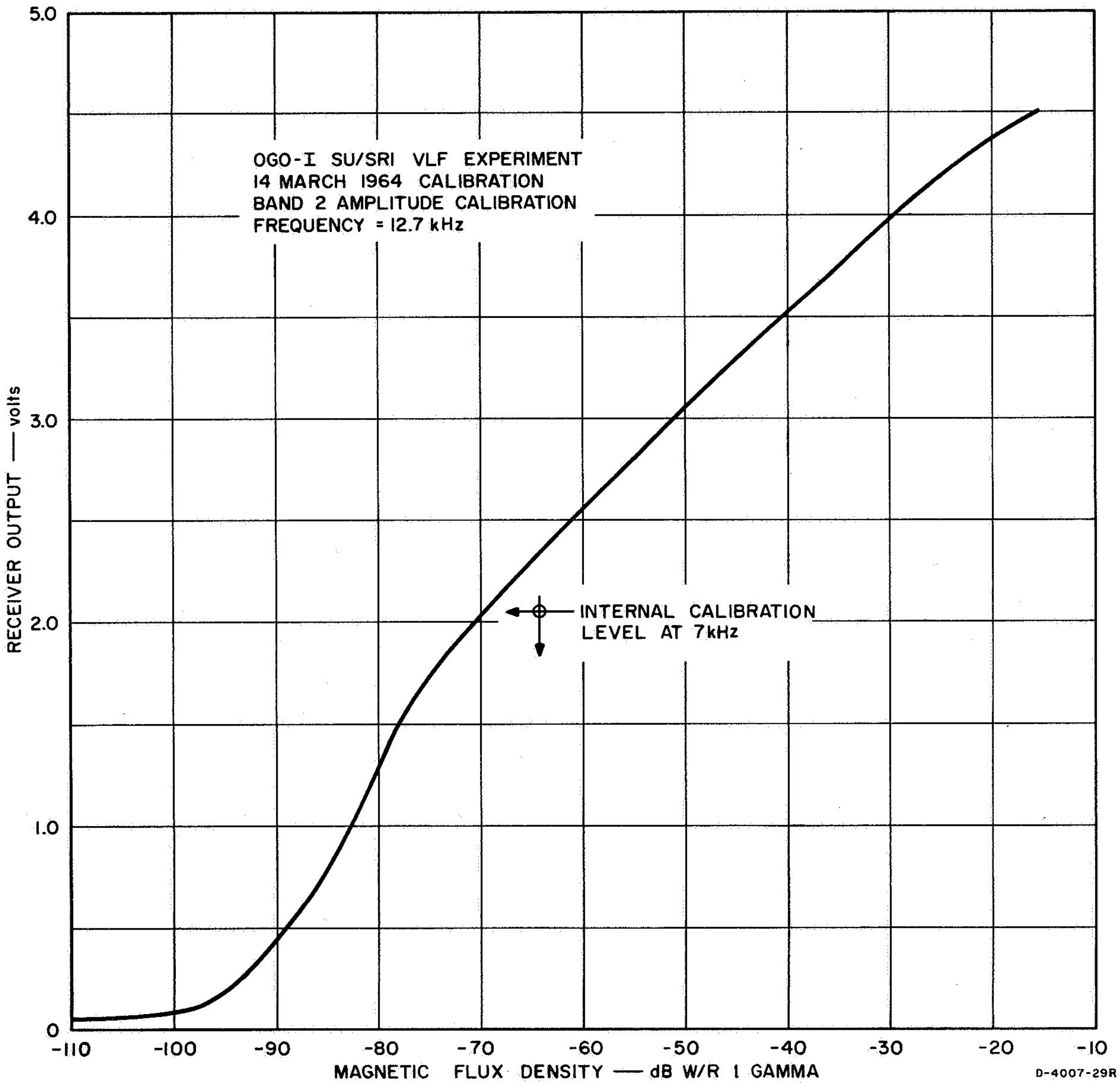


FIG. 2.6 BAND 2 CALIBRATION CURVE

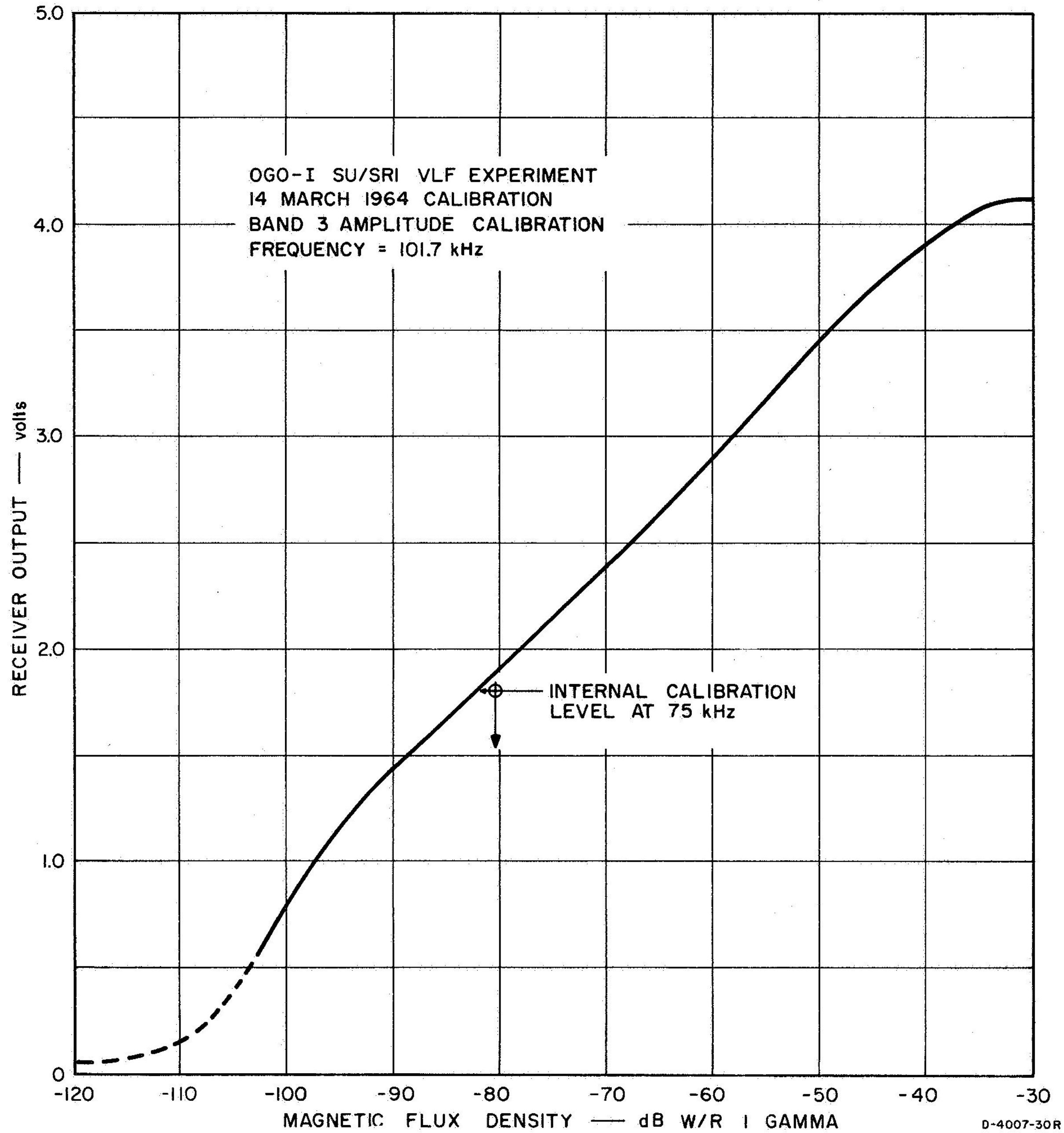


FIG. 2.7 BAND 3 CALIBRATION CURVE

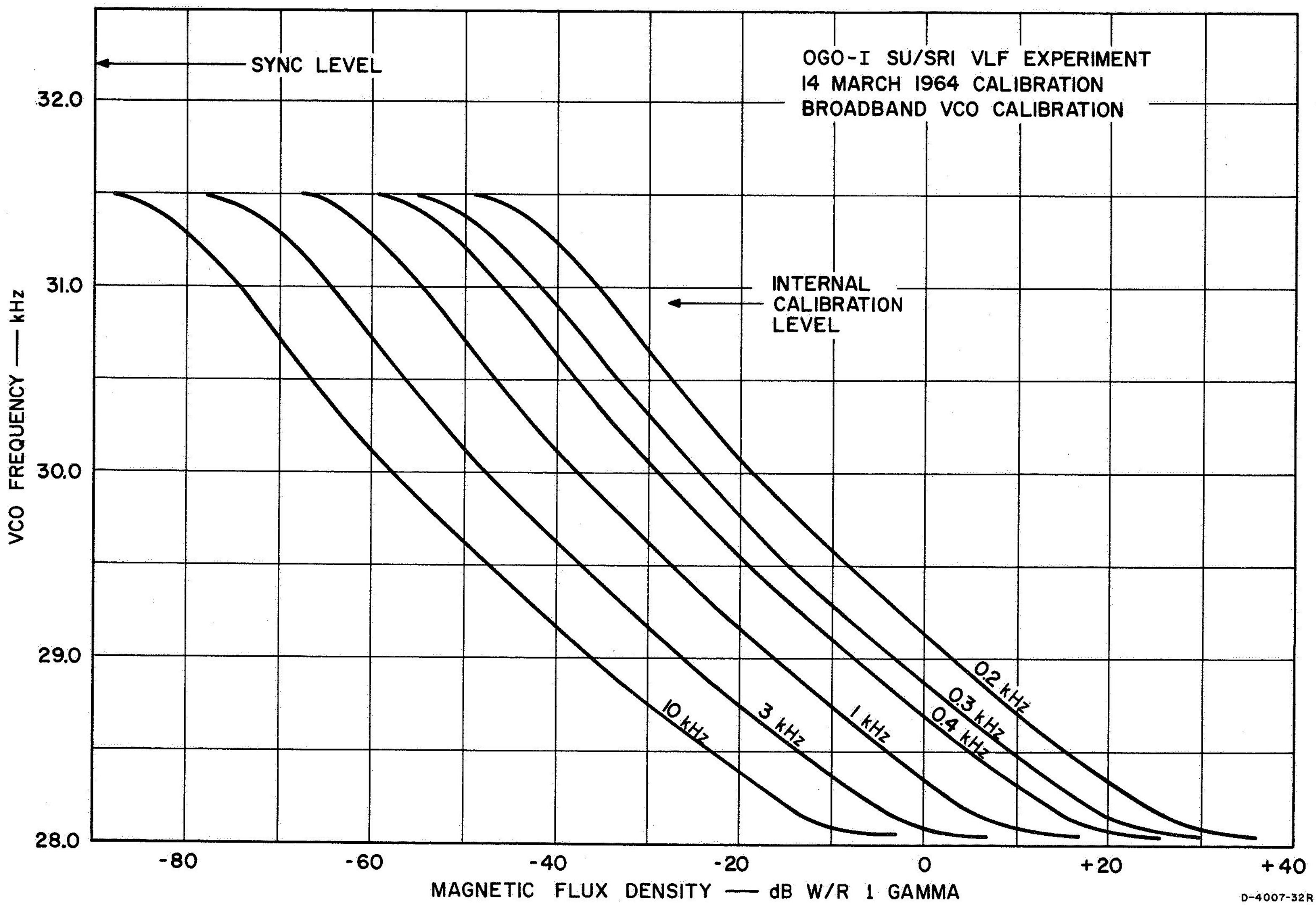


FIG. 2.8 BROADBAND VCO CALIBRATION CURVE

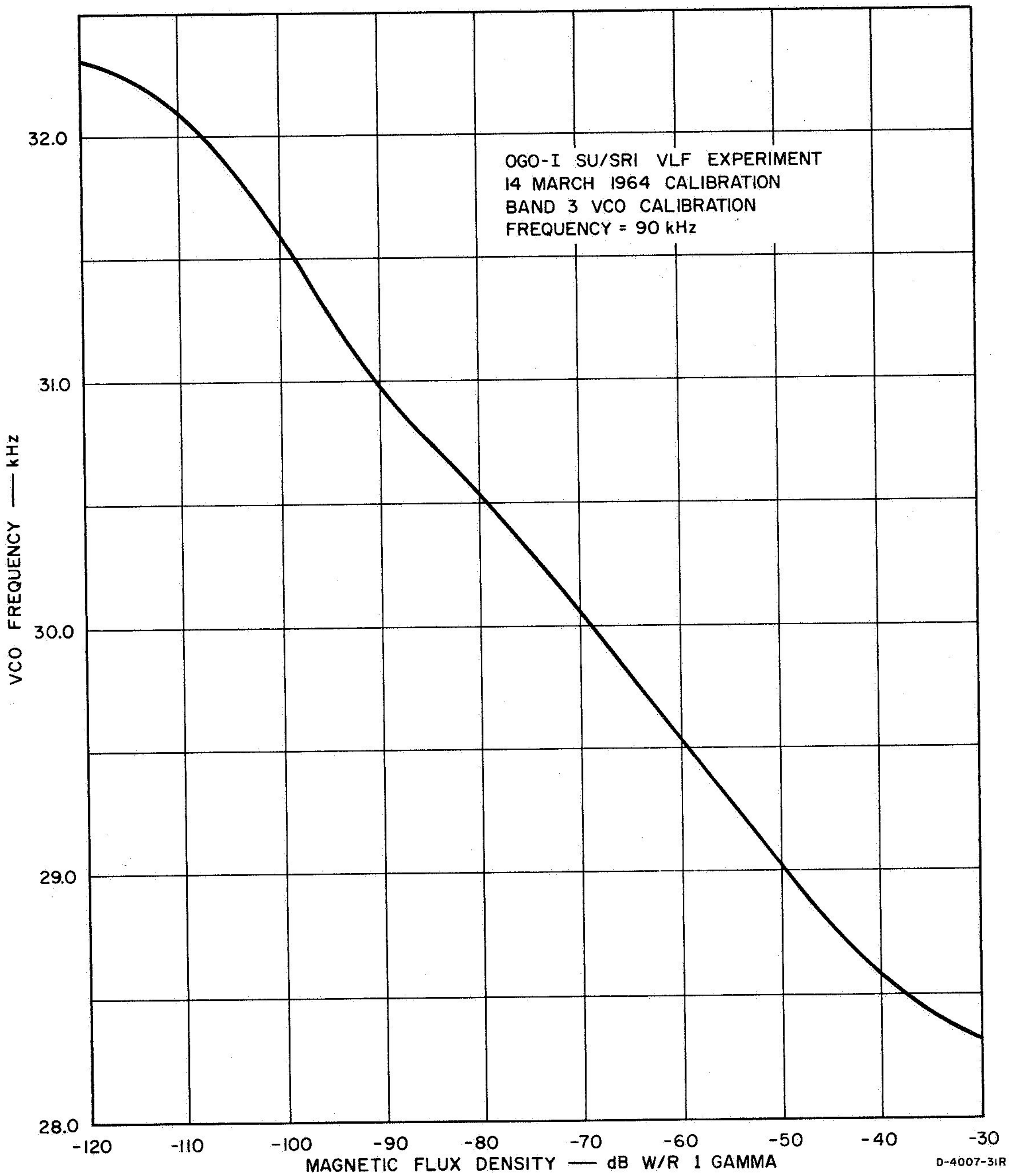


FIG. 2.9 BAND 3 VCO CALIBRATION CURVE

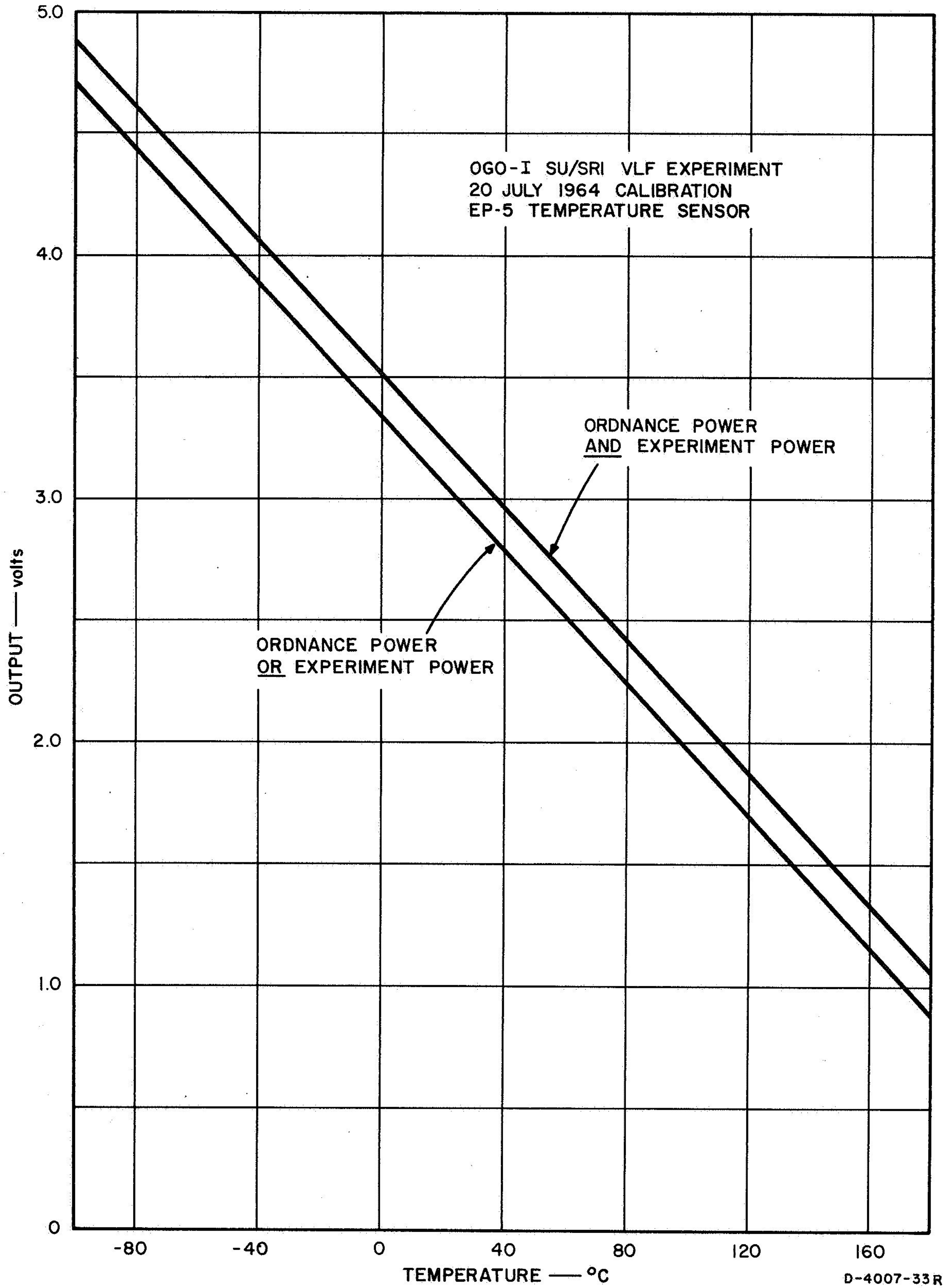


FIG. 2.10 CALIBRATION CURVE OF EP-5 TEMPERATURE SENSOR

There are two different calibration curves: one for both ordnance power and experiment power on, the other for either ordnance power or experiment power on.

2.4 Summary of Technical Characteristics

2.4.1 Receiver Characteristics

Table 2.1 summarizes the characteristics of the Experiment A-17 components.

Table 2.1

PHYSICAL CHARACTERISTICS OF EXPERIMENT A-17

Dimensions:	Main-Body Package.	19.0 X 15.5 X 9.2 cm
	Preamplifier	4.7 X 4.7 X 7.8 cm
	Antenna (furled)	13 X 22 X 9 cm
	Antenna (unfurled)	2.9m-diameter torus of 7.6-cm-diameter thin-wall Mylar-aluminum tube
	Antenna Inflation Mechanism	
	Gas Bottle.	5 X 12 cm (diameter X length)
	Actuator.	6.4 X 4.4 X 2.2 cm
	Relief Valve.	2 X 2 X 6 cm
Weight:	Main-Body Package.	800g
	Preamplifier	130g
	Antenna.	315g
	Antenna Inflation Mechanism	
	Gas Bottle.	320g
	Actuator.	115g
	Relief Valve.	45g
	Gas (2000 psi argon). . .	20g
Input Power:	28.5 ±5 Vdc, 33 mA	

2.4.2 Data Outputs and Receiver Modes

Table 2.2 summarizes the electrical characteristics of Experiment A-17.

Table 2.2

ELECTRICAL CHARACTERISTICS OF EXPERIMENT A-17

Parameter	Receiver Band 1			Receiver Band 2			Receiver Band 3			Broadband
Frequency Range (kHz)	0.2-1.6			1.6-12.5			12.5-100			0.3-12.5
Threshold Sensitivity (γ)	$(2.4-0.3) \times 10^{-4}$			$(2.4-0.3) \times 10^{-5}$			$(6.0-0.8) \times 10^{-6}$			3×10^{-2} -3×10^{-5}
Dynamic Range (dB)	90			90			80			80
Analog Output (V)	0-5.12			0-5.12			0-5.12			---
LO Frequency (kHz)	3.11-1.71			24.9-14.0			199.5-112			---
IF Frequency (kHz)	3.31			26.5			212			---
Bandwidth, -3 dB (Hz)	40			160			600			---
Bandwidth -60 dB (Hz)	450			1300			4500			---
ΔF/Step (Hz)	5.4			43			344			---
Data Rate (kb/s)	1	8	64	1	8	64	1	8	64	---
Sweep Rate (Steps/s)	1.68	13.9	111	1.68	13.9	111	1.68	13.9	111	---
Sweep Time (s)	147	18.4	2.3	147	18.4	2.3	147	18.4	2.3	---
Output Time Constant (ms)	880	110	14	340	49	4.4	150	18	2	---

The sweep-frequency receivers are automatically stepped (with the characteristics given in Table 2.2) whenever the receiver is in Modes 1 and 2; in Mode 3 these receivers can be stepped by ground command to any desired frequency. One command will step the receivers one step; another command will step the receiver eight steps (see Table 2.3).

Table 2.3

GROUND COMMANDS AND RECEIVER MODES OF EXPERIMENT A-17

Command*	Octal Code	Receiver Mode, Receiver, Configuration, Data Outputs†
PC 40 <u>on</u>	253	Power <u>on</u>
PC 40 <u>off</u>	273	Power <u>off</u>
IC 16	173	<u>Mode 1</u> Bands 1, 2, and 3 sweeping; broadband amplitude applied to 30-kHz VCO; Band 2 LO applied to SP TLM
IC 17	114	<u>Mode 2</u> Bands 1, 2, and 3 sweeping; broadband amplitude applied to 30-kHz VCO; broadband spectrum applied to SP TLM; Band 2 LO applied to SP TLM
IC 18	134	<u>Mode 3</u> Bands 1, 2, and 3 fixed frequency; Band 3 amplitude applied to 30-kHz VCO; Band 3 phase (53 kHz) applied to SP TLM; Band 2 LO applied to SP TLM. First IC 18 after IC 16 or IC 17 sets receiver frequency to high end; next IC 18 resets frequency to low end; subsequent IC 18's step frequency by one step.
IC 19	154	Same mode and data output as IC 18 except following frequency sequence: First IC 19 after IC 16 or 17 sets receiver frequency to high end; next IC 19 resets frequency to the seventh step from the low end; subsequent IC 19's step frequency by eight steps.
IC 20	174	Antenna inflation

*Power command (PC) and impulse command (IC).

†In all modes, digital data are taken from the outputs of Bands 1, 2, and 3.

2.4.3 Antenna Temperature Monitor

The temperature at the antenna manifold is monitored by a sensor with temperature range of approximately -100 to +200°C. The temperature sensor output is applied to the Wideband telemetry system (Subcommutator Word 83), and samples are obtained every 147, 18.4, and 2.3 seconds for 1-, 8-, and 64-kb/s data rate, respectively.

2.4.4 Automatic Calibrator

Every sixteenth sweep of the sweep-frequency receivers, a spectrum of 1 kHz and its harmonics are applied to the antenna for calibration purposes.

3. DESCRIPTION OF SPACECRAFT

3.1 Description of Data-Handling Subsystem

The OGO-I spacecraft data subsystem is briefly described in this chapter. A more detailed discussion of the complete spacecraft system is available,[1] and the OGO specifications have been published by Goddard Space Flight Center (GSFC).[4] The major elements of the subsystem are shown in a simplified block diagram (Fig. 3.1). Each of the two identical data-handling units (Equipment Groups 1 and 2) includes a set of time multiplexers or commutators and an analog-to-digital converter. Either analog or digital data can be handled by the commutator. The four analog outputs of Experiment A-17--the Bands 1, 2, and 3 receivers and the antenna temperature sensor--are sampled by both equipment groups.

The output of one equipment group is recorded by one of two tape recorders (the second recorder being a backup unit or standby) at a rate of 1 kb/s. Each recorder contains sufficient tape to store data for 12 hours; the second unit switches on automatically when the first is full. They are read out periodically in reverse time sequence (accelerated rewind) and transmitted to ground stations at 64 kb/s. The second equipment group is used to telemeter data to a ground station in real time at 1, 8, or 64 kb/s on command from the ground station. The equipment groups can be interchanged on command, so that either can be used for real-time data transmission and the other for data storage.

One of the two redundant 400.25-MHz Wideband transmitters--Wideband A and Wideband B--using pulse-code modulation/phase modulation (PCM/PM) telemeters the data from the real-time equipment group or from the tape recorders, as directed by ground command. One transmitter drives the directional antenna, while the other drives the omnidirectional antenna. Each transmitter supplies 10W to the antenna.

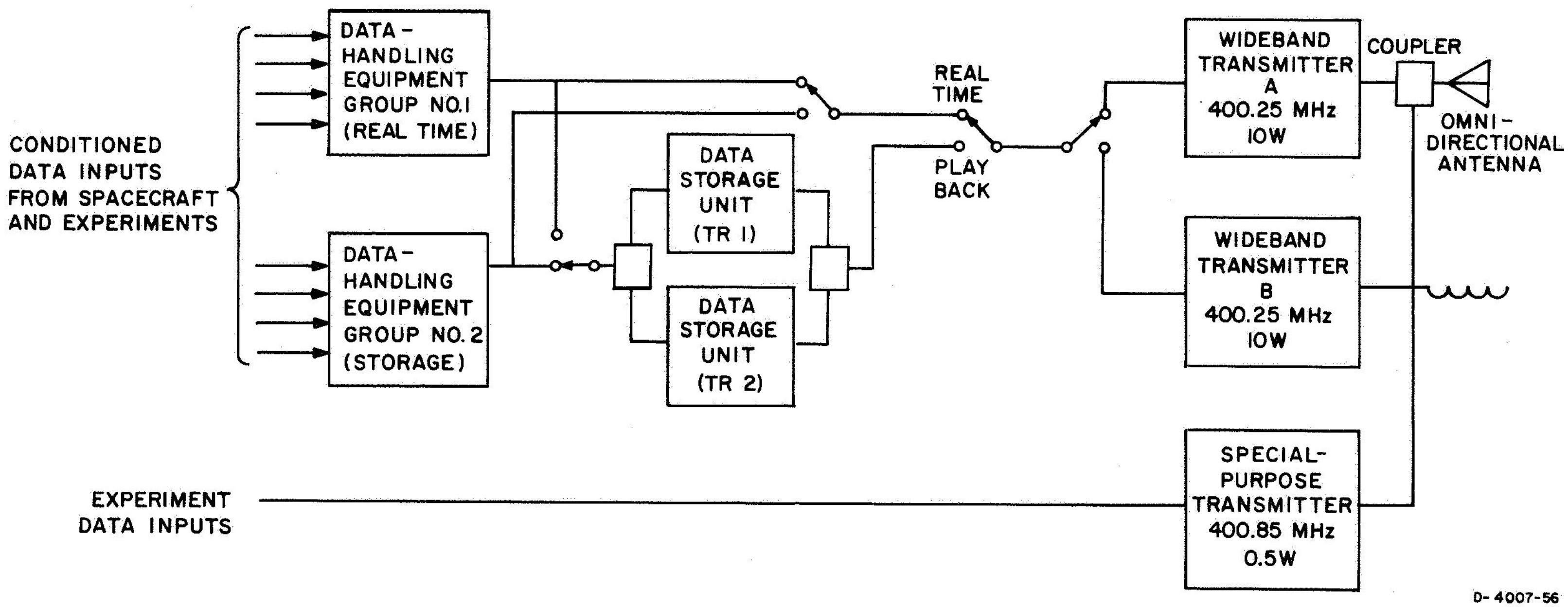


FIG. 3.1 BLOCK DIAGRAM OF OGO-1 TELEMETRY SUBSYSTEM
Adapted from Ref. 1, p. 2293.

The second major portion of the data subsystem is the Special Purpose transmitter operating at 400.85 MHz. It supplies 0.5W to the omnidirectional antenna. This transmitter was designed to telemeter data from experiments that are incompatible with the time-sharing feature of the Wideband system or signals to be telemetered in completely unprocessed form. It is phase modulated by one or more signals, to a total of five, each signal 5V peak to peak and within the 0.3-to-100-kHz range. Experiment A-17 has two signal channels on the Special-Purpose baseband. One channel is a 30-kHz VCO modulated by the broadband amplitude in Modes 1 and 2 or the Band 3 amplitude in Mode 3. The other channel consists of a 0.3-to-12.5-kHz signal in Modes 2 and 3, 15-to-25-kHz local oscillator signal in all modes, and a 53-kHz Band 3 phase signal in Mode 3. All the analog data are being processed and stored by Stanford University, with major emphasis on the production of Rayspan records[5] of the 0.3-to-12.5-kHz broadband spectrum signal.

3.2 Description of PCM Telemetry System

OGO-I uses a split-phase PCM/PM digital telemetry system in which each telemetry frame contains 128 9-bit words. Twelve words of the frame contain fixed inputs: the frame sync pattern, the spacecraft clock readout, the spacecraft data-handling status words, and sampling of the three spacecraft subcommutators. Assignments of data outputs to the remaining words of the 128-word frame vary in format according to whether the outputs are supplied in the main frame mode, in one of the 32 flexible format modes, or in the accelerated subcommutator mode. The main frame commutator assigns outputs to the 128-word frame from all experiments except one (Experiment A-14) which does not use the spacecraft PCM data format. Selection of one of the flexible format modes by ground command only replaces main frame assignments, and ground command assigns outputs from the spacecraft subcommutator to the 128-word frame. Selection of a flexible format for assigning outputs to the 128-word frame results, in effect, in supercommutation of subcommutated outputs in the main frame. Selection of the accelerated subcommutator mode by ground command assigns subsystem outputs from spacecraft Subcommutator 2 (Main Commutator Word 98) to the 116 unfixed words of the main frame.

Experiment A-17 was assigned and uses Main Commutator Words 46, 47, 48, 110, 111, and 112 and Word 83 in Subcommutator 1 in both equipment groups. Band 1 output data appear on Main Commutator Words 46 and 110, Band 2 data on Main Commutator Words 47 and 111, Band 3 output data on Main Commutator Words 48 and 112, and the temperature sensor data on Subcommutator Word 83. A detailed discussion of the OGO-B telemetry format can be found in a NASA Report.[6] The differences between the OGO-A (OGO-I) and OGO-B (OGO-III) formats, which do not directly affect Experiment A-17, are also described in that report.

3.3 Orbital Operations

3.3.1 General

Since the launching of the OGO-I satellite, its operation in orbit has been controlled by commands transmitted from the ground. These commands originate in the OGO Operations Control Center (OGO CC) under the direction of the Project Operations Director (POD). Experiment requirements must be optimally matched by the POD to the satellite, experiment, data acquisition, command, communication, and data processing capabilities existing at the time specified in the operations plan. The requirements for a revolution plan are supposed to be coordinated as shown in the flow chart, Fig. 3.2.

For example, in a typical Experiment A-17 operation it is desired to tune the Band 3 receiver to a U.S. Navy VLF station. From the orbit predictions, a period is selected when the satellite will be in position to receive signals transmitted from the ground and when the transmitter will be operating. From station coverage predictions, it is then determined that data can be taken and that commands can be sent to the satellite, received, and verified. Discussions are then held with the POD or his representative to determine whether any spacecraft, communication, or other operational constraints will affect the operation. If no conflicts are found, the operation is scheduled in the revolution operations plan.

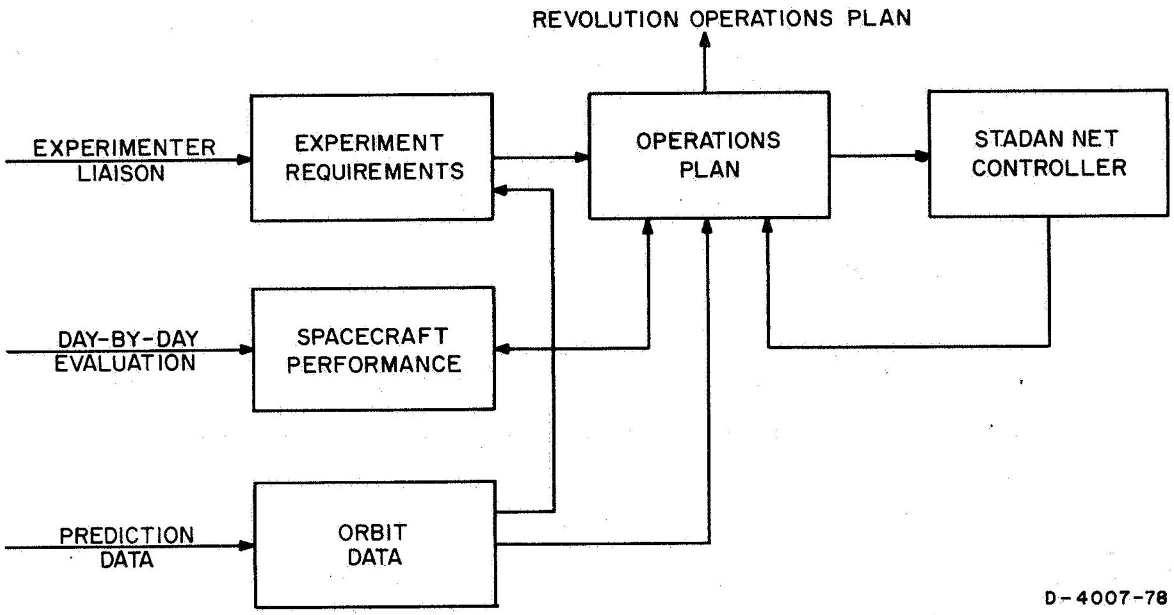


FIG. 3.2 FLOW CHART OF GENERATION OF REVOLUTION OPERATIONS PLAN

Several special operations have been successfully conducted, despite almost daily changing of the constraints and conditions. The success of these operations is a tribute to the Operations personnel at NASA/GSFC.

Systems operations are:

(1) Prelaunch operations

(2) Post-launch operations

(a) Initial

(b) Routine

(c) Special-event.

Plans were generated for both prelaunch operations and post-launch operations, with no deviations allowed unless authorized by the POD.

3.3.2 Prelaunch Operations

Prelaunch operations were conducted to ensure the compatibility of the interface between the OGO-I satellite and the ground station. Data tapes and orbit tapes were generated to check out the GSFC data processing operation and to provide the experimenters with inputs to their computer programs for prelaunch debugging purposes. The operational requirements for Experiment A-17 were formulated, presented, and coordinated, and an initial experiment turn-on sequence was established. Final instrument calibrations were performed during these tests.

3.3.3 Initial Operations

The initial phase of operations began at lift-off and continued through the first two revolutions, approximately five days. During that period, the aliveness and operational status of the experiment and spacecraft subsystems were almost continuously monitored and evaluated. Since the satellite did not function as planned, deviations from the planned sequencing and timing of events were authorized in an attempt to isolate and evaluate the malfunctions. When the satellite had failed to attitude stabilize as planned, it was spun until all the altitude-control-system gas was exhausted before a spin-stabilized attitude was achieved. This severely limited the time when sufficient power was available for spacecraft and experiment operations and when real-time data could be received at the ground stations. Consequently, all the operational plans were revised. (For details, see Ref. 8.)

3.3.4 Routine Operations

The routine phase of operations commenced when the initial operations phase had terminated. The day-to-day scheduling, evaluating, and operations now took place, with some interruptions during minimum power seasons. The data acquisition plan was revised to acquire as large a quantity of data as possible, since the lifetime of the spacecraft was uncertain. Even when sufficient power was available, data acquisition was limited to those occasions when the directional antenna was pointing approximately toward the earth or when the spacecraft was near perigee and the omnidirectional antenna could be used.

3.3.5 Special-Event Operations

Special-event operations have been implemented following the occurrence of geophysical events. In each case, a special plan appropriate to the event reported has been put into effect to acquire data as specified by existing individual experimenters. Experiment A-17 has usually called the OGO CC directly when a specific event has been observed on the ground or a change in the observatory status has been desired. On several occasions, the instrument has been put into Mode 3 and tuned to a particular VLF station. To ensure proper tuning of the Band 3 local oscillator, the Special-Purpose telemetry from the spacecraft has been monitored by using the 150-foot dish antenna at the Stanford Center for Radio Astronomy. When corrections have been required, they have been telephoned directly to the personnel at OGO CC, and the commands have been transmitted and verified in real time.

4. DATA ACQUISITION

4.1 NASA/GSFC Data Acquisition System

Data telemetered from OGO-I are recorded at the Space Telemetry and Data Acquisition Network (STADAN) stations listed in Table 4.1. The stations designated as primary are distinguished by their greater command capability, a real-time data link with GSFC, and the greater telemetry reception capability afforded by their 85-foot parabolic antennas. Otherwise, primary and secondary stations alike acquire and record both PCM and Special-Purpose telemetry from OGO-I. The general flow of data at the acquisition stations is indicated on Fig. 4.1.

Table 4.1

OGO-I SPACE TELEMETRY AND DATA ACQUISITION STATIONS

STADAN Station and Location	Letter Codes	No. Code	Real-Time Data Link to GSFC	Function	Diameter of Parabolic Antenna (ft)
Gilmore Creek, Alaska	SKA ULASKA	19	Yes	Primary	85
Rosman, North Carolina	ROS ROSMAN	20	Yes	Primary	85
Johannesburg, Union of S. Africa	JOB JOBURG	16	None	Secondary	40
Quito, Ecuador	QUI QUITOE	5	None	Secondary	40
Santiago, Chile	SNT SNTAGO	8	None	Secondary	40

During a routine real-time pass at a station, the 136-MHz tracking beacon or the 400.85-MHz Special-Purpose transmitter signal is acquired first, since the tracking beacon is not turned off and the Special-Purpose transmitter is normally left on all the time. After a spacecraft signal has been acquired, commands are sent to turn on the

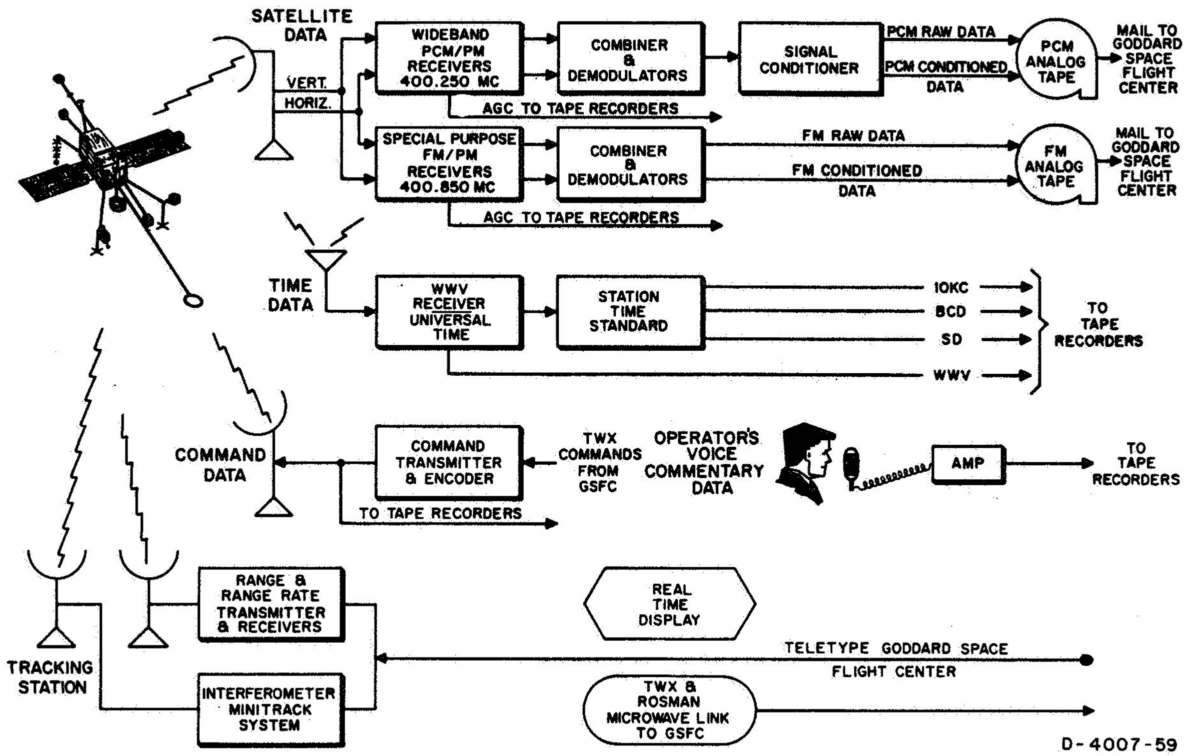


FIG. 4.1 FLOW CHART OF DATA AT GROUND STATIONS
From Ref. 6, p. 41.

Wideband transmitter, to dump on-board tape recorders, or to configure the spacecraft or experiments according to the revolution operations plan. All data are then recorded, as shown in Fig. 4.1. At the end of a pass when the signals start to fade and before loss of signal, commands are sent to turn off the Wideband transmitter. The PCM data are recorded on magnetic tape in analog form with the track assignments shown in Table 4.2. The Special-Purpose data are recorded with the track assignments shown in Table 4.3. Formats for the BCD, SD, and WWV time codes appear in Fig. 4.2.

Table 4.2*

MAGNETIC TAPE TRACK
ASSIGNMENTS FOR WIDEBAND (PCM/PM) DATA

Track	Record Amplifier	Source	Signal
1	Direct	Multiplex system	Receiver AGCs and 10-kHz reference
2	Direct	Transmitter control panel	Commands
3	Direct	Diversity combiner	Unconditioned PCM data
4	Direct	Time standard system	BCD time code
5	Direct	PCM-DHE	Conditioned PCM data
6	FM	Time standard system	Serial decimal time code
7	Direct	Audio amplifier	Voice commentary and WWV time

Table 4.3†

MAGNETIC TAPE TRACK ASSIGNMENTS
FOR SPECIAL-PURPOSE (FM/PM) DATA

Track	Record Amplifier	Source	Signal
1	Direct	Time standard system and multiplexed system	Receiver AGCs and 10-kHz reference
2	Direct	Transmitter control panel	Commands
3	Direct	Diversity combiner	FM data
4	Direct	Time standard system	BCD time code
5	Direct	Time standard system	100-kHz reference
6	FM	Time standard system	Serial decimal time code
7	Direct	Audio amplifier	Voice commentary and WWV time

*Based on Ref. 6, page 41.

†Based on Ref. 6, page 43.

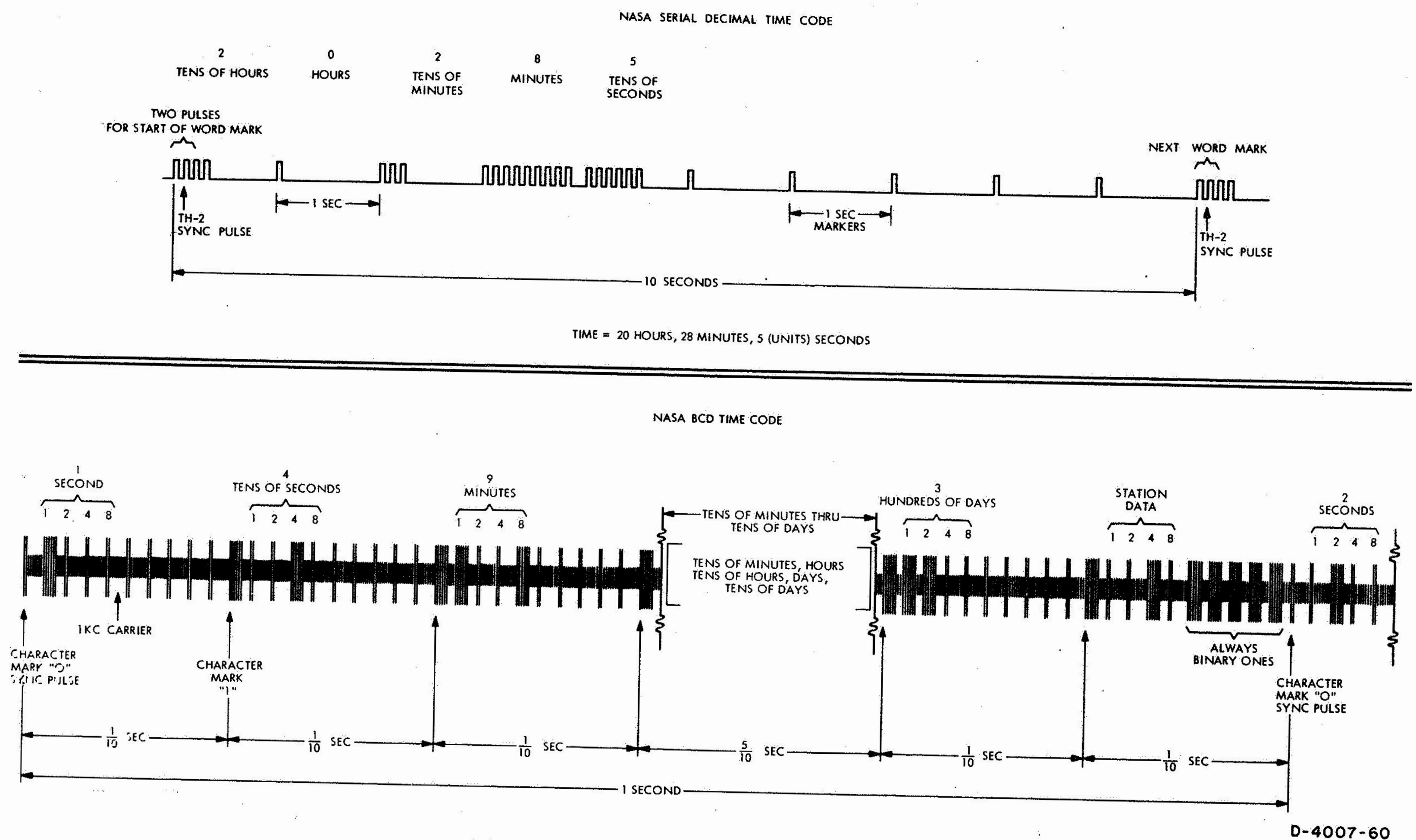


FIG. 4.2 BCD, SD, AND WWV. TIME CODES
From Ref. 6, p. 36

Details of the time-code transmissions from radio station WWV. For this particular example, the signals indicate the 50th second of the 23rd minute, of the 10th hour, of the 121st day of the current year. One second later, the first of the "units" pulses in the group designating "seconds" will change from "0" (a 2-millisecond pulse) to "1" (a 6-millisecond pulse), indicating the 51st second.

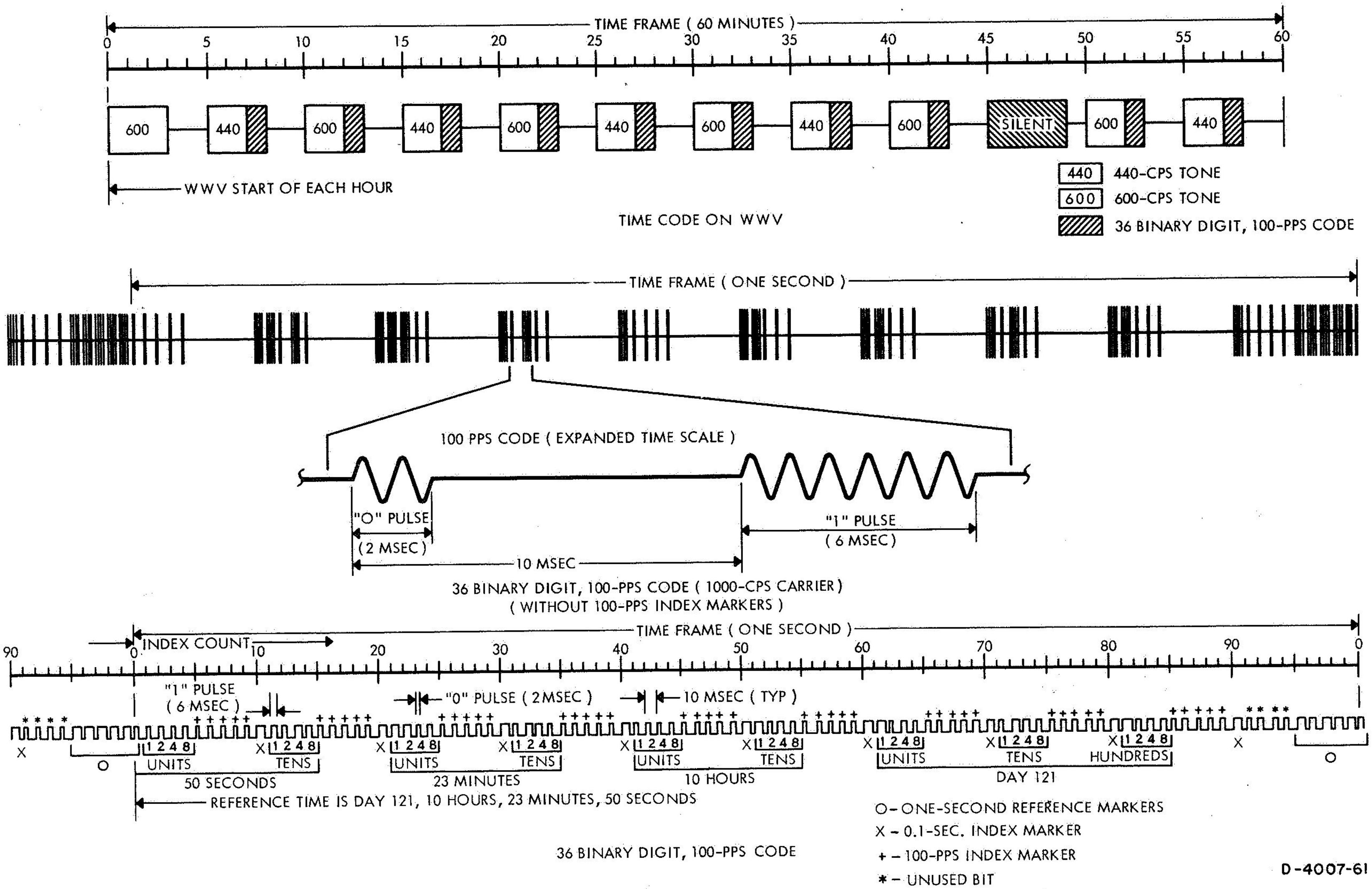


FIG. 4.2 (Continued)
From Ref. 6, p. 37.

4.2 SU/SRI Data Acquisition System

The design of the OGO-I Experiment A-17 instrument provided, in addition to its data-processing capability, a check of the status of the experiment over the Special-Purpose telemetry link. The original plan was to use the satellite tracking station operated by Professor O. K. Garriott at SU to receive OGO-I analog data. Real-time analog data were to be processed at SU so that satellite-received signals could be compared with ground-received signals and used to determine the status of the experiment. During the first two orbits of OGO-I, attempts were made to use Garriott's quadhelix antenna to receive OGO-I Experiment A-17 data. These attempts were unsuccessful, because a poor signal-to-noise ratio resulted from the spacecraft's Special-Purpose telemetry antenna not being pointed toward the earth.

The greater sensitivity of the 150-ft-diameter parabolic dish antenna at the Stanford Center for Radio Astronomy enabled analog data to be received at certain positions of the satellite orbit. To facilitate reception, SU and SRI personnel made several modifications to the big dish. The feed system was tuned; an illumination feed was installed to check the polarization and sensitivity of the system before operations; a C-core preamplifier (26-dB gain, 4.5-dB noise figure), furnished by Stanford University, was installed on one polarization; and a tuned diode preamplifier (0.8-dB loss, 2.5-dB noise figure), borrowed from Professor Bracewell's group, was installed on the other polarization. A Defense Electronics Industries telemetry receiver, a Sanborn strip chart recorder, a Pacific Instruments tape recorder, and a Special-Purpose telemetry analyzer built by SRI completed the system. Until 3 December 1964, the big dish was operated two or three passes a week by SRI personnel; subsequently, SU personnel continued the operation. In all, approximately 50 hours of analog data were acquired by using the big dish.

5. DATA PROCESSING

5.1 NASA/GSFC Data Processing System

The data processing methods, computer programs, hardware systems, and processing controls employed by NASA during launch, back-up, and post-launch operations, during quick-look passes, and for normal production processing of OGO data have been described in a NASA report.[6] The highlights of the material covered in this NASA report are briefly mentioned here, and certain vital information--such as data tape formats, orbit tape formats, and command-card formats--is reproduced here for completeness.

5.1.1 NASA/GSFC Data Format

The processing of PCM data for OGO-I follows approximately the chronological order shown in Fig. 5.1. Upon receipt, magnetic tapes

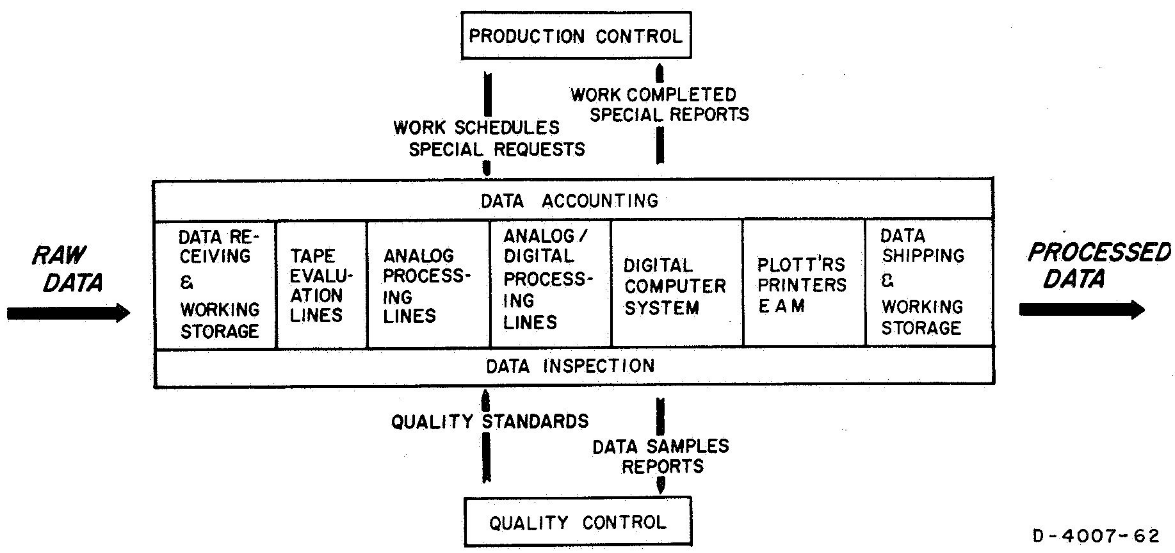


FIG. 5.1 NASA/GSFC PRODUCTION FLOW AND CONTROL CHART
From Ref. 6, p. 46.

containing raw PCM data from the acquisition ground stations are placed in the analog tape library. (These analog tapes yield digital data after processing and are not to be confused with the Special-Purpose data tapes which also contain analog data.) Tapes from shipments from each station are evaluated, rated, and returned to storage. The analog PCM data tapes are stored in the Central Processing Facility, GSFC, until the data contained on them have been processed. One month after the processed data have been released to the experimenters, the PCM analog data tapes are sent to the Federal Archives for dead storage. The processing line converts the analog data into digital data for digital computer processing, decodes the timing data, determines their quality, and decodes spacecraft commands. In digital format, the PCM data go through intermediate processing, consisting of first-order editing, quality control, and time correction, using a digital computer.

A buffer tape is the output of this first pass of processing. The buffer tapes are fed into an Edit Program that generates edit records. The edit tapes contain records of data in chronological order, regardless of receiving station or missing data. The computer inserts frames of fill data in an edit record to maintain format integrity and time consistency. When fill data have been inserted, the status field of the appropriate frame is flagged. The fill data word format is shown in Table 5.1. Quality control, data, and time status fields (Tables 5.2, 5.3, and 5.4) are associated with each frame of data, regardless of whether the data are useful or fill data.

Table 5.1

DATA WORD FORMAT

Normal Data Word*		Fill Data Word*	
0	X	1	0
0	X	0	0
0	X	0	0
X	X	0	0
X	X	0	0
X	X	0	0

*Two characters per word.

Table 5.2*

QUALITY CONTROL STATUS FIELD

Bit†	State	Representation for Field F1, Quality Control Status**
1-6		Total bit errors in the 27-bit-frame sync word
7	1	Fill data
8	1	Beginning of a subcommutator sequence
9-10	0-0	Real-time data, 1 kb/s
9-10	1-0	Real-time data, 8 kb/s
9-10	0-1	Real-time data, 64 kb/s
9-10	1-1	Command storage playback data
11	1	Suspect data. This flag appears when the bit errors in the frame sync word are ≥ 3.
12	1	Corrected time

*Based on Ref. 6, page 63.

†Bit 12 is the most significant bit; Bit 1 is the least significant bit.

**Computer-determined.

Table 5.3*

DATA STATUS FIELD

Bit†	State	Representation for Field F3, Data Status**
1-7		Subcommutator count; 0 - 127
8	1	Lock mode; in frame sync
8	0	Flywheel mode; still in lock with bit errors in frame sync exceeding tolerance
9	1	In subcommutator sync
9	0	Not in subcommutator sync
10-12		Number of bit errors in frame sync

*Based on Ref. 6, page 65.

†Bit 12 is most significant; Bit 1 is least significant.

**Data status flags are a hardware function rather than computer-determined.

Table 5.4*

TIME STATUS FIELD

Bit	State	Representation for Field F2, Time Status†
1	1	BCD decoded time agrees with the accumulating register.
2	1	BCD decoded time disagress with the accumulating register.
1 + 10	1	BCD decoded time agrees with both the accumulating register and Serial Decimal decoded time. The experimenter can have good confidence in time when these flags appear.
1 + 9	1	BCD decoded time agrees with the accumulating register but disagrees with SD decoded time.
2 + 3	1	BCD decoded time disagrees with the accumulating register but agrees with SD decoded time. The experimenter should not have confidence in this time.
2 + 4	1	BCD decoded time disagrees with both the accumulating register and SD decoded time. The experimenter should not have confidence in this time.
5	1	SD decoded time agrees with accumulating register.
6	1	SD decoded time disagrees with accumulating register.
5 + 7	1	SD decoded time agrees with accumulating register but not with BCD decoded time.
5 + 8	1	SD decoded time agrees with both the accumulating register and BCD decoded time. Again, the experimenter can have good confidence in time when these flags appear.
6 + 7	1	SD decoded time disagrees with both the accumulating register and BCD decoded time. The experimenter should not have confidence in this time.
6 + 8	1	SD decoded time disagrees with the accumulating register but agrees with BCD decoded time.
11	1	BCD to Binary Converter circuit is in error. The experimenter should not have confidence in this time.
12		Not used at present.

*Based on Ref. 6, p. 64.

†Time status flags are a hardware function rather than computer-determined. Experimenters should ignore this flag; it does not pertain to their data.

Time correction is a major function of the Edit Program; a description of that program is reproduced here (Ref. 6, page 70):

"(1) Real Time Data:

"Using selected tapes, ground station time is corrected for transmission delay from the spacecraft and the delay from WWV to the station. The high resolution points of the updated spacecraft clock are then found, and the corresponding times (GMT) are then associated with them. The GMT and high resolution points are then punched onto cards. These cards are fed into another program which performs one to nth degree polynomial fits on the time. The residuals of the fits are compared and the best are chosen. The coefficients of the fits are fed back into the Edit Program and all times on all tapes over specified intervals are corrected based upon this criterion. Residuals between computed time and the corrected ground time are printed to obtain further confidence in the accuracy.

"(2) Playback data:

"The coefficients of the fit previously chosen using real-time data over a selected interval of time are input to the Edit Program when processing playback data. Since ground station time associated with the playback data has no value, no residuals are produced nor other comparisons made. Time computed from the polynomial fit is applied after the high resolution points of the spacecraft clock are found. If for some reason (e.g., noise), no high resolution points can be determined, the data will be processed by the Quick-Look Time Correction and Reformat Program.

"Note: When the time correction procedures contained in the Edit Program are used, the time of any particular frame is accurate to ±4 ms. If the Quick-Look time correction procedures are used, time is accurate to within 1 sec. The status field (Table 5.2) contains a flag which, when lit, signifies that the time on the tape has been computed using the extensive time correction procedures of the Edit Program."

After each edit file has been completed, extensive quality control checks are made. If the edit file passes all the tests, then the data in it are ready for decommutation. The decommutated data are then put into a requested format for the experimenter.

Data may go from the buffer tapes directly to decommutated data tape without going through the Edit Program. When this is done, the resulting data are termed quick-look digital data. Since quick-look data do not undergo the time correction and quality control that edited data do, they must be used carefully. They are useful for debugging data reduction and analysis programs and for a first look at important geophysical phenomena (such as a solar flare). This quick-look data processing operation is not to be confused with another quick-look operation performed in the OGO CC. This second quick-look operation generates strip chart records containing experiment data. These data have usually been recorded in real time from a Rosman or Ulaska pass and are used to determine whether the experiment is performing properly. The records can be hand-scaled to get results for quick analysis.

Each Experiment A-17 data tape contains one or more files of data, to a maximum of six. Each file contains an identifying label record, several experiment data records, and an end-of-file marker. All the data records of a file contain data taken at the same spacecraft data bit rate. Playback data files are separated from real-time data files. A file contains only one ground station pass. A change in bit rate, spacecraft equipment group, or spacecraft format results in a new file. Experiment A-17 data are on 1/2-inch-wide magnetic tape written in binary mode (odd parity) with 556 BPI. Each 9-bit telemetered word is represented by two 6-bit characters, as shown in Table 5.1. Three zeros precede the first-(2^8), second-(2^7), and third-(2^6) highest-order bits in the first character. The 6 low-order bits go in the second 6-bit character. Each file is labeled as shown in Table 5.5. Each data record is in the format shown in Table 5.6.

Table 5.5

EXPERIMENT A-17 LABEL RECORD FORMAT

Character	Identification
1-5 + space	Satellite identification Example: 64021, where 64 = year of launch 02 = beta 1 = object.
7-8 + space	Year
10-12 + space	Station number--Example: 001 for Blossom Point
14-15 + space	Analog file number
17-20 + space	Analog tape number
22-23 + space	Buffer file number
25-28 + space	Buffer tape number
30-32 + space	Date of data digitization (day of year)
34-66	Identical to Characters 1-33, unless an error was found in those characters. If that is the case, this portion of the record contains the corrected values of that field.
67 + space	Type of data contained in file: 0 = 1 kb/s real time 1 = 8 kb/s real time 2 = 64 kb/s real time 3 = command storage playback
69-71 + space	Day of year } Start time of data
73-77 + space	Seconds of day } Start time of data
79-90	Spares
91-94 + space	Master binary tape number
96-97	Master binary file number
98-120	Blanks

Table 5.6

EXPERIMENT A-17 DATA RECORD FORMAT

Character	Location	Identification
1-2		Day count of year (1-365)
3-4	D(99,14)	EP-5 temperature (E-17)
5-6	D(99,37)	Experiment mounting plate temperature (+Z door) (E-17)
7-8	D(98,47)	Load bus voltage (D-10)
9-10	D(98,35)	Special-Purpose telemetry power-forward (C-9)
11-12	D(98,3)	Special-Purpose telemetry power-reverse (C-10)
13-14	D(97,83)	Experiment subcommutation data
15-16	D(98,81)	ADHA case temperature
		F24 for EG-1; F32 for EG-2
		In-flight calibration: EG-1 / EG-2
17-18	D(98,82)	F25 / F33
19-20	D(99,81)	F26 / F34
21-22	D(98,83)	F27 / F35
23-24	D(99,82)	F28 / F36
25-26	D(98,84)	F29 / F37
27-28	D(99,83)	F30 / F38
29-30	D(98,85)	F31 / F39
31-36 + 36N		Time field: milliseconds of day for first bit of Main Commutator Word 1
37-42 + 36N	EG(33,j) EG(34,j) EG(35,j)	Spacecraft accumulated time
43-48 + 36N		Three status fields: information regarding the data contained in each frame
43-44		Quality control status
45-46		Time status
47-48		Data status
49-50 + 36N	EG(65,j)	Data identification word Bit — Item 1-7 — Subcommutator position 8 — Execute-relay state 9 — Cross strap
51-52 + 36N	EG(66,j)	Data identification word* Bit — Item 1 — Data type 2-4 — Mode 5-9 — Flexible format number
53-54 + 36N	EG(67,j)	Data identification word† Bit — Item 1 — Data type 2-4 — Mode 5-9 — Flexible format number
55-66 + 36N	EG(46,j) EG(110,j) EG(47,j) EG(111,j) EG(48,j) EG(112,j)	Experimental data words
The difference between N and j lies in that $0 \leq N \leq 127$ and $1 \leq j \leq 128$		

*Data being examined.
†Data not being examined.

5.1.2 NASA/GFSC Orbit Format

The attitude-orbit tapes contain the orbital parameters and the satellite attitude information. These tapes are written in binary floating-point format, with a 36-bit field. A file is defined as one revolution, from one north-going geographic equator crossing to the next. The period of time for a single revolution of OGO-I is approximately 64 hours. The first record of each file is a label record containing information such as the start and end times of orbit, the start and end times of eclipse, the orbit number, the data sampling rate, and the time of predicted noon turn. The remaining orbit data records of the file give the satellite position and velocity in celestial inertial coordinates, the actual and ideal main-body positions, the orbital-plane experimental packages (OPEP) and solar array orientations, the height above the earth, the magnetic and geographic coordinates of the subsatellite point, the true anomaly, and other data. These data are computed for 1-minute intervals and written on the attitude-orbit tape for each revolution of the satellite. The format for the attitude-orbit tapes appears on Table 5.7.

Table 5.7

ATTITUDE-ORBIT TAPE FORMAT*

A. Attitude-Orbit Label Record†				
Word	Symbol	Function or Name	Description, Notes	Units
1	ID	Identification		None
2 3 4		Start time of orbit		Year Month Day
5 6	tEl	Eclipse start		Day Millisecond of day
7 8	tE2	Eclipse end		Day Millisecond of day
9 10	tOl	Orbit start	Time of the ascending node, that point in the equatorial plane through which the satellite passes while going from south to north. See Fig. 5.2(a).	Day Millisecond of day
11 12	tO2	Orbit end	End time of this orbit and start time of the next orbit, i.e., time of the next ascending node. See Fig. 5.2(a).	Day Millisecond of day
13 14	tn	Noon turn	Time of predicted noon turn. The paddles are able to rotate through only 180°. When the paddles are looking straight up (φ_p = 270°) or straight down (φ_p = 90°) at the sun, the spacecraft turns 180° about the body Z axis, so the paddle may reverse its direction of rotation and still continue to follow the sun. See Data Record Word 121.	Day Millisecond of day
15 16	τ	Epoch	Arbitrary reference time at which the orbital elements were computed	Day Millisecond of day
17	Δt	Sampling rate	The values in the data records are given at intervals of $t_a + \Delta t$. The value of Δt is expected to be 60,000 ms (1 min).	Milliseconds
18		Orbit number	Orbit 0 is from launch to the first ascending node. Orbit 1 starts at the first ascending node and ends at the second ascending node. The n^{th} orbit starts at the n^{th} ascending node. See Fig. 5.2(a).	None
19	a	Semi-major axis	Semi-major axis of the orbital ellipse (1 earth radius = 6371.2 km). See Fig. 5.2(b).	Earth radii
20	e	Eccentricity	Eccentricity of the orbital ellipse. See Fig. 5.2(b).	None
21	i	Inclination	Angle of the orbital plane and the earth's equatorial plane. See Fig. 5.2(c).	Degrees
22	Ω	Longitude of ascending node	Angle between the Geocentric Equatorial Inertial (GEI) X axis (γ) and the position vector of the ascending node. See Fig. 5.2(d).	Degrees
23	$\dot{\Omega}$		Rate of change of Ω	Degrees/day
24	ω	Argument of perigee	Perigee is that orbital point nearest the earth; ω is the angle between the position vector of the ascending node and the position vector of perigee. See Fig. 5.2(a).	Degrees
25	$\dot{\omega}$		Rate of change of ω	Degrees/day
26	T	Period	Time required to make one orbit	Minutes
27	$\dot{T}$		Rate of change of T	Minutes/day
28-99			Spares	

*This table is based on pp. 81 through 97 of Ref. 6.

†Greenwich Mean Time is used whenever time appears in the table, unless otherwise noted.

Table 5.7 (continued)

Attitude-Orbit Label Record (continued)				
Word	Symbol	Function or Name	Description, Notes	Units
100	r	Spin rate	If the spacecraft is spinning about an axis stabilized with respect to the craft, the spin rate, r, is given as a positive number.	Degrees/ second
101	$\dot{r}$		Rate of change of r	Degrees/ second/day
102-104	A	GEI spin axis	A = (Ax, Ay, Az) is the spin axis as a unit vector in GEI coordinates (GEIC). A is defined so the spin rate, r, is positive with respect to the right-hand rule.	None
105-107	Ab	Body spin axis	Ab = (Abx, Aby, Abz) is the spin axis as a unit vector represented in body coordinates. This representation will not change when the spin axis is stabilized with respect to the spacecraft.	None
108-116	R1	First spin matrix	In each of R1, R2, and R3, the first three words contain the values in the top row of the matrix, the second three words those in the middle row, and the last three words those in the bottom row.	None
117-125	R2	Second spin matrix		None
126-134	R3	Third spin matrix	Let: $b(T_i) = \begin{bmatrix} bXx & bYx & bZx \\ bXy & bYy & bZy \\ bXz & bYz & bZz \end{bmatrix}$, where bXx through bZz are defined in Data Record Words 49-57, i.e., bx, by, and bz at T_i, where T_i is defined in Word 1 of the Data Record. Let $\bar{b}(T)$ be the interpolation of $b(T_i)$ to time T with no correction for spin. Then $\bar{b}(T) = \bar{b}(T)\ R1 + \bar{b}(T)\ R2 \sin\sigma\ (T) + b(T)\ R2 \cos\sigma\ (T) = \bar{b}(T)\ \lvert R1 + R2 \sin\sigma\ (T) + R3 \cos\sigma\ T \rvert$, where b(T) defines the body coordinate axes is GEIC, as in $b(T_i)$, and $\sigma(T)$ is the angle from the spin vector $A(T_i)$ = (Ax, Ay, Az) at time T_i to spin vector A(T) at time T.	None
135-250			Spares	

Table 5.7 (continued)

B. Attitude-Orbit Data Record				
Word	Symbol	Function or Name	Description, Notes	Units
1	T1	Time	Day count	Days
2			All data in this record correspond to T1.	Milliseconds of day
3 4 5	TL	Local time	Local Apparent Solar Time of subsatellite point	Hours Minutes Tenths of minutes
6	α	Right ascension	Angle from the first point of Aries (γ) to the equatorial plane projection of the spacecraft position vector. See Fig. 5.2(e).	Degrees
7	δ	Declination	Angle from the equatorial plane projection of the spacecraft position vector to the spacecraft position vector. See Fig. 5.2(e).	Degrees
8-10	P	Position vector	P = (Px, Py, Pz) is the position vector of the spacecraft in GEIC. See Fig. 5.2(e).	Kilometers
11-13	V	Velocity vector	V = (Vx, Vy, Vz) is the direction and magnitude of the spacecraft velocity in GEIC. See Fig. 5.2(e).	Kilometers/ second
14-16	S	Solar vector	S = (Sx, Sy, Sz) is the position vector of the sun in GEIC.	Kilometers
17	φ	Latitude	Geodetic latitude of subsatellite point on the spheroid. North is +; South is -. The International Spheroid is used: a = semi-major axis = 6378.388 km; f = flattening = 297 = a/a-b.	Degrees
18	λ	Longitude	Geodetic longitude of subsatellite point on the spheroid. East is +; West is -.	Degrees
19	h	Height	Height of satellite above the shperoid. See Fig. 5.2(e).	Kilometers
20	ν	True anomaly	Orbital central angle between perigee and satellite with earth as focus. See Fig. 5.2(b).	Degrees
21	Φ	Sun-earth-satellite angle	Angle between the satellite position vector and the sun position vector	Degrees
22-24	bXI	Ideal body roll axis	bXI = (bXIx, bXIy, bXIz) is the ideal body X axis.*	None
25-27	bYI	Ideal body pitch axis	bYI = (bYIx, bYIy, bXIz) is the ideal body Y axis.*	None
28-30	bZI	Ideal body yaw axis	bZI = (bZIx, bZIy, bZIz) is the ideal body Z axis.*	None
31-33	PXI	Ideal paddle roll axis	PXI = (PXIx, PXIy, PXIz) is the paddle X axis.*	None
34-36	PYI	Ideal paddle pitch axis	PYI = (PYIx, PYIy, PYIz) is the paddle Y axis.*	None
37-39	PZI	Ideal paddle yaw axis	PZI = (PZIx, PZIy, PZIz) is the paddle Z axis.*	None
40-42	EXI	OPEP ideal roll axis	EXI = (EXIx, EXIy, EXIz) is the OPEP X axis.*	None
43-45	EYI	OPEP ideal pitch axis	EYI = (EYIx, EYIy, EYIz) is the OPEP Y axis.*	None
46-48	EZI	OPEP ideal yaw axis	EZI = (EXIx, EZIy, EZIz) is the OPEP Z axis.*	None
49-51	bX	Actual body roll axis	bX = (bXx, bXy, bXz) is the body X axis.*	None
52-54	bY	Actual body pitch axis	bY = (bYx, bYy, bYz) is the body Y axis.*	None
55-57	bZ	Actual body yaw axis	bZ = (bZx, bZy, bZz) is the body Z axis.*	None

*As a unit vector in GEIC.

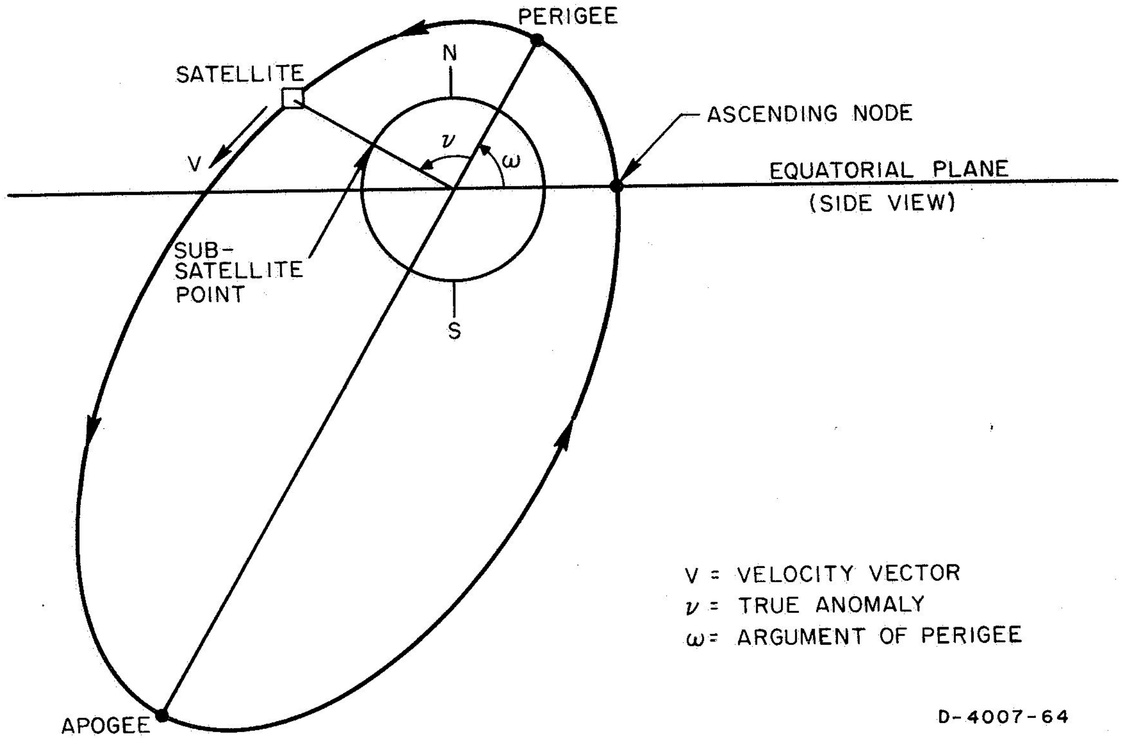
Table 5.7 (continued)

Word	Symbol	Function or Name	Description, Notes	Units
		B. Attitude-Orbit Data Record (continued)		
58-60	PX	Actual paddle roll axis	PX = (PXx, PXy, PXz) is the paddle X axis.*	None
61-63	PY	Actual paddle pitch axis	PY = (PYx, PYy, PYz) is the paddle Y axis.*	None
64-66	PZ	Actual paddle yaw axis	PZ = (PZx, PZy, PZz) is the paddle Z axis.*	None
67-69	EX	Actual OPEP roll axis	EX = (EXx, EXy, EXz) is the OPEP X axis.*	None
70-72	EY	Actual OPEP pitch axis	EY = (EYx, EYy, EYz) is the OPEP Y axis.*	None
73-75	EZ	Actual OPEP yaw axis	EZ = (EZx, EZy, EZz) is the OPEP Z axis.*	None
76	R	Magnetic range	$R \approx L \cos^2 (\varphi m)$, where L is the McIlwain parameter of the magnetic shell containing the spacecraft, and φm is the magnetic latitude of the spacecraft. Note that R is analogous to, but not equal to, $\|P\|$, the magnitude of the position vector.	Earth radii
77	φm	Magnetic latitude	Latitude of the spacecraft in geomagnetic coordinates. At the magnetic equator, $\varphi m = 0$. See Fig. 5.2(f), for relationship between L and and R.	Degrees
78	L	McIllwain parameter	A megnetic shell parameter that is almost constant along lines of force; L is used to label each shell. Note that in the ideal case (dipole field) L is the magnitude of the position vector on the magnetic equator of the line of force. See Fig. 5.2(f).	Earth radii
79	B	Field strength	Magnitude of magnetic field strength at the spacecraft. See Fig. 5.2(a).	Gamma
80	B/B_o	Ratio	B is defined above. B_o is the equatorial field strength of the shell. See Fig. 5.2(f).	None
81	φI	Ingress latitude	Latitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft enters the earth. See Fig. 5.2(f).	Degrees
82	λI	Ingress longitude	Longitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft enters the earth. See Fig. 5.2(f).	Degrees
83	φE	Egress latitude	Latitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft leaves the earth. See Fig. 5.2(f).	Degrees
84	λE	Egress longitude	Longitude of the point on the surface of the earth at which the magnetic line of force passing through the spacecraft leaves the earth. See Fig. 5.2(f).	Degrees
85-87	$\hat{B}$	B vector	$\hat{B}$ = (Bx, By, Bz) is the direction of the magnetic line of force expressed as a unit vector in GEIC.	None
88-90	Bb	B body	Bb = (Bbx, Bby, Bbz) is the unit direction vector, $\hat{B}$, expressed in the body coordinate system.	None
91-93	BP	B paddle	BP = (BPx, BPy, BPz) is the unit direction vector, $\hat{B}$, expressed in the paddle coordinate system.	None
94-96	BE	B OPEP	BE = (BEx, BEy, BEz) is the unit direction vector, $\hat{B}$, expressed in the OPEP coordinate system.	None

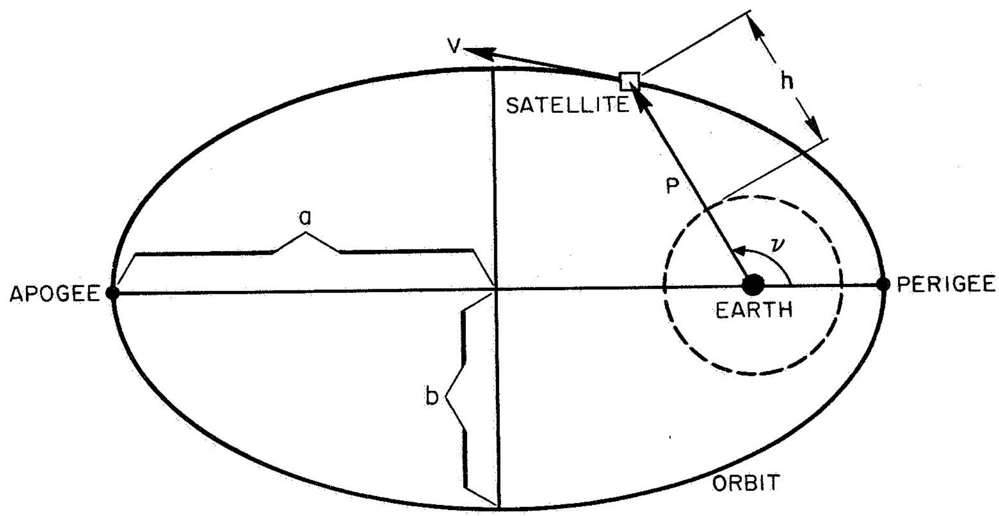
*As a unit vector in GEIC.

Table 5.7 (continued)

B. Attitude-Orbit Data Record (continued)				
Word	Symbol	Function or Name	Description, Notes	Units
97-99	$B\hat{B}G$	$B\hat{B}$ geodetic	$B\hat{B}G$ is the product of the field strength, B, times the unit vector, $\hat{B}G = (\hat{B}GE, \hat{B}GN, \hat{B}GV)$, where $(\hat{B}GE, \hat{B}GN, \hat{B}GV)$ is the unit vector, $\hat{B}$, expressed in geodetic coordinates. Note that this is a left-handed system, not a right-handed one.	
100-108	TGSE	GSE transformation	The transformation matrix that changes the GEI representation of a vector to GSE (Geocentric Solar Ecliptic) representation. The vector remains fixed. Words 100, 101, and 102 contain the values for the top row of the matrix, Words 103, 104, and 105 those for the middle row, and Words 106, 107, and 108 those for the bottom row. Any vector, v, in GEIC is transformed by the relation $V_{GSE} = (\text{matrix})\ V_{GEI} = TGSE\ V_{GEI}$.	None
109-117	TGSM	GSM transformation	The transformation matrix that changes the GEIC representation of a vector to GSM (Geocentric Solar Magnetic) representation. The vector remains fixed. Words 109, 110, and 111 contain the top row of the matrix, Words 112, 113, and 114 the middle row, and Words 115, 116, and 117 the bottom row.	None
118-120	A	GEI spin axis	A = (Ax, Ay, Az) is the unit spin axis in GEIC.	None
121	φP	Paddle angle	The paddle shaft angle is $\varphi P = 90°$ when the paddle is looking in the direction of the body +Z axis (toward earth); $\varphi_p = 180°$ when the paddle is looking in the body -Y axis direction (away from the OPEP); and $\varphi_p = 270°$ when the paddle is looking in the body -Z axis direction (away from the earth). Movement of the paddle is restricted such that $90 \le \varphi_p \le 180°$.	
122	ψE	OPEP angle	The OPEP shaft angle is $\psi E = 0$ when the OPEP is looking in the body +X axis direction (away from the spacecraft); $\psi E = 90°$ when the OPEP is looking in the body +Y axis direction (away from the spacecraft), and $\psi E = 270°$ when the OPEP is looking in the body -Y axis direction (over the spacecraft). The OPEP can rotate through more than 360°.	Degrees
123	None	Attitude data flag	Flag assigned the floating point value -1.0 if any housekeeping discrepancy is detected.	None
124	None	NO DATA flag	A value of 2^k or any combination of 2^{k1}, 2^{k2}..., 2^{k5} in the NO DATA flag signifies that the data indicated were not available. The ideal value is used when the actual value is not available. The following table is used in Words 124 and 125: Bit Value — Data Word 2^0 — Roll 2^1 — Pitch 2^2 — Yaw 2^3 — ψE (OPEP shaft angle) 2^4 — φP (Paddle shaft angle) 2^5 — Array error (Note that Word 124 is a floating-point word.)	
125	None	SUSPECT DATA flag	Flag warning that the indicated data are doubtful. The indications are the same as for Word 124.	None
126	T2	Time	$T2 = T1 + \Delta t$	Days
127-250			Same as Words 2-125, except that time T2 is used.	See words 2-125.



(a)



$e = \sqrt{1 - b^2/a^2}$ = ECCENTRICITY
a = SEMI-MAJOR AXIS
b = SEMI-MINOR AXIS
P = POSITION VECTOR
V = VELOCITY VECTOR
ν = TRUE ANOMALY
h = HEIGHT OF SATELLITE

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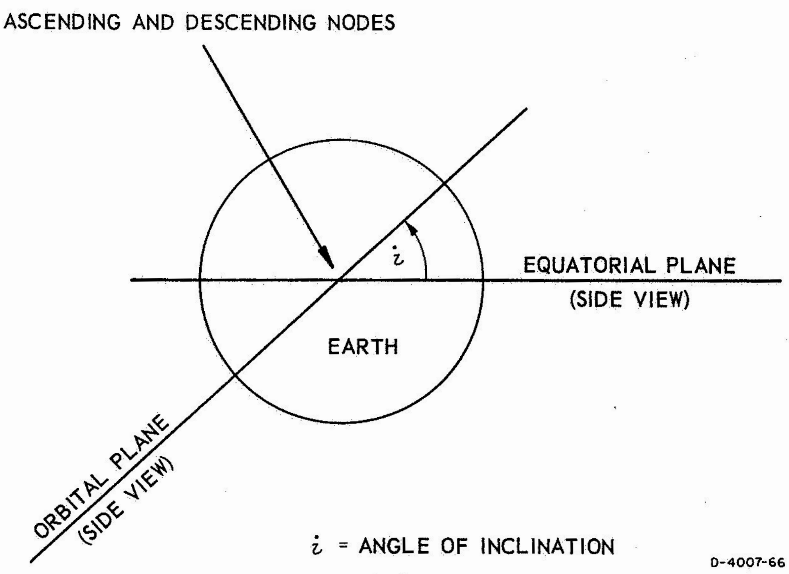
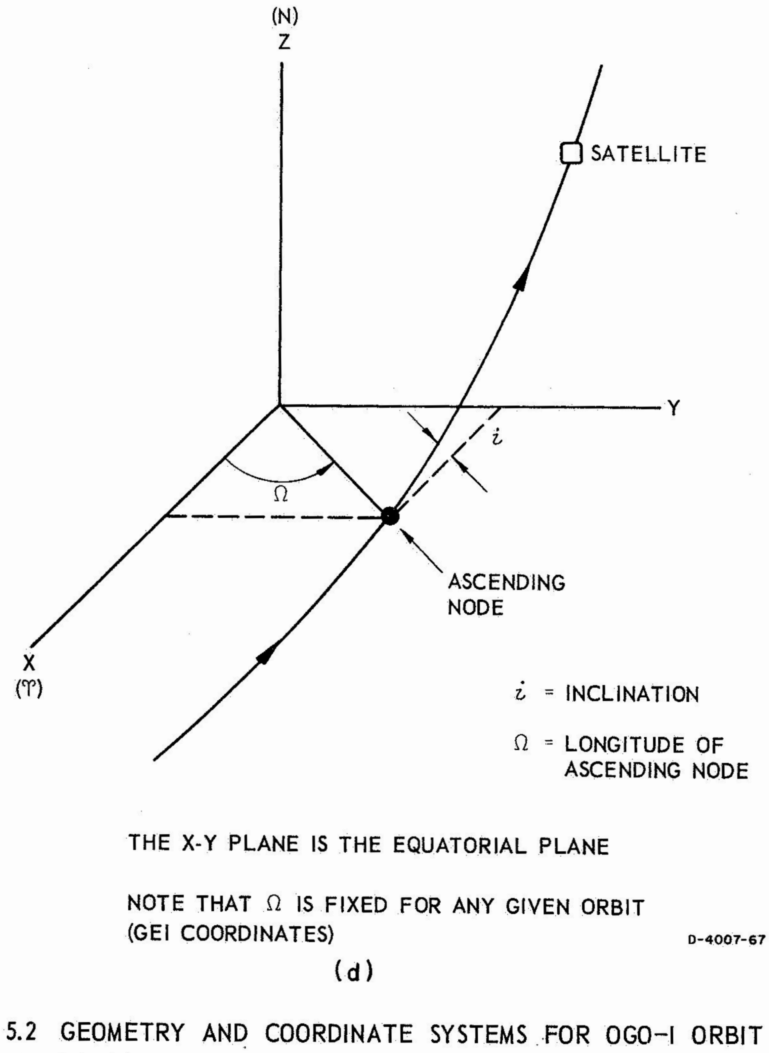
(b)

FIG. 5.2 GEOMETRY AND COORDINATE SYSTEMS FOR OGO-I ORBIT
(a) Adapted from Ref. 6, p. 100 (b) Adapted from Ref. 6, p. 98

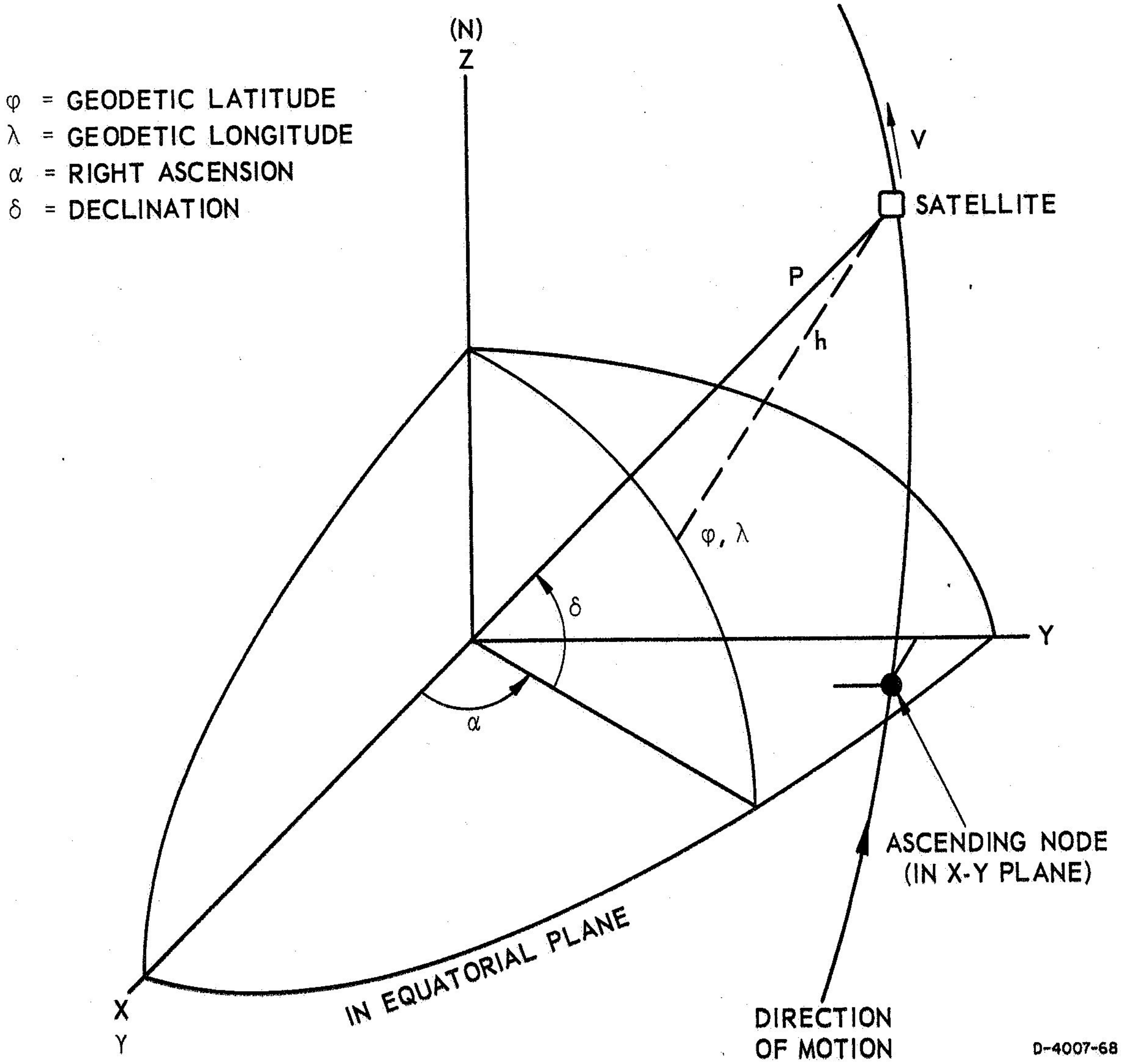


(c)



(d)

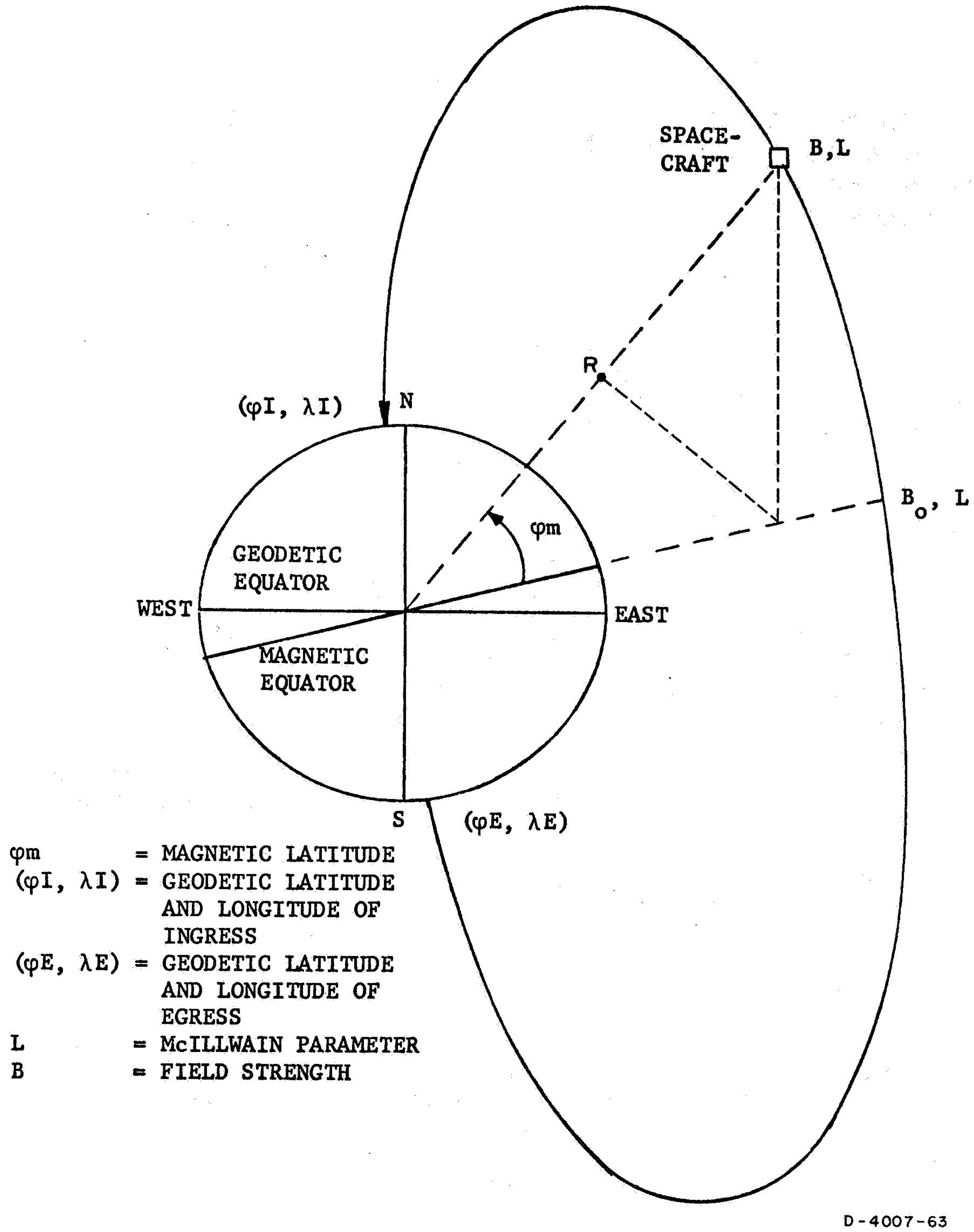
FIG. 5.2 GEOMETRY AND COORDINATE SYSTEMS FOR OGO-I ORBIT
(c) Adapted from Ref. 6, p. 99 (d) Adapted from Ref. 6, p. 101



NOTE THAT α IS MEASURED FROM THE FIRST POINT ARIES (♈) WHICH IS FIXED, AND λ IS MEASURED FROM GREENWICH WHICH SPINS WITH THE EARTH.

(e)

FIG. 5.2 GEOMETRY AND COORDINATE SYSTEMS FOR OGO-I ORBIT
(e) Adapted from Ref. 6, p. 102



(f)

FIG. 5.2 GEOMETRY AND COORDINATE SYSTEMS FOR OGO-I ORBIT
(f) Adapted from Ref. 6, p. 103

5.1.3 Experiment A-17 Commands

The functions of the OGO-I spacecraft, as well as the operations of the experiments are directed by ground station commands. Experiment A-17 uses two power commands and four impulse commands. An additional command was used early in the flight to deploy the antenna. The impulse commands (IC) allocated to Experiment A-17 are IC 16 through IC 20. The two power commands (PC) are PC 40 on and 40 off. All commands are transmitted to the satellite in octal. The commands for Experiment A-17, their functions, and their octal representation are as follows:

IC	Function	Octal Representation
16	Sweeping mode, broadband off	173
17	Sweeping mode, broadband on	114
18	Fixed-frequency mode, step by 1	134
19	Fixed-frequency mode, step by 8	154
20	Antenna deployment	153
PC		
40	Turn experiment on	253
40	Turn experiment off	273

The commands sent to the satellite are logged into revolution reports; each report lists the sequence of commands transmitted during one revolution; it includes the date, time, and station from which the command was transmitted, octal identification, a description of the command, and any remarks about the command transmission or verification. The revolution reports are the primary source of command information. In addition to the revolution reports, punched IBM cards are generated by GSFC from the original data tapes. The command card format is a standard 80-column card format and has three major sections (see Fig. 5.3). The first section gives the satellite identification, year data were recorded, station number, and analog tape number. The second section gives the day count and the hour, minute, second, and millisecond of the day that the command was sent. The third section gives the octal address and the octal location of the command.

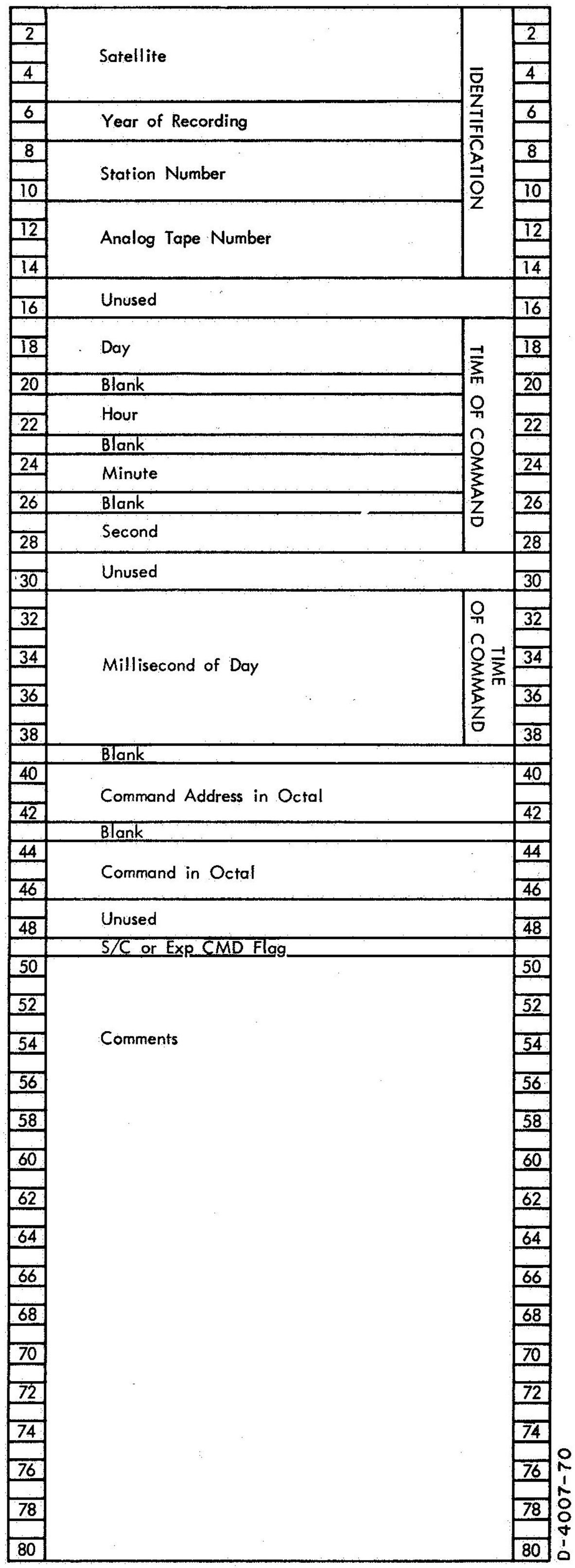


FIG. 5.3 COMMAND CARD FORMAT
From Ref. 6, p. 119.

5.2 SRI Digital Data Processing System

5.2.1 Inputs

After the PCM telemetry signal transmitted from OGO-I is received at the data acquisition stations, it is demodulated and recorded on magnetic tape, along with timing and command information. These tapes are then sent to the Data Processing Branch of GSFC for further processing and individual experiment decommutation and distribution, as mentioned in the previous section.

The Data Processing Branch at GSFC is responsible for the preliminary processing of the experimental data from Experiment A-17 up to and including decommutation and preparation of attitude-orbit tapes and command cards. The project operations personnel at GSFC prepare operations summaries for distribution to the experimenters. Digital data processing responsibility beyond this point has been delegated to SRI by SU. In all, NASA/GSFC provides SRI with six inputs to its data processing system: data tapes, attitude-orbit tapes, command cards, operation summaries, strip charts, and an orbit ephemeris. The data tapes are of three varieties: real-time, stored, or quick-look.

The experimental data tapes sent to SRI by NASA/GSFC are accompanied by a tape log sheet with the following information:

(1) The ground station where the data were acquired

(2) The edit tape number

(3) A file number

(4) The decommutation run number

(5) The date of recording

(6) The start and stop time of each data file

(7) The number of files for each tape in the run.

The log sheets that accompany the attitude-orbit tapes give the name and number of revolutions covered on each tape.

Every data or attitude-orbit tape received by SRI or generated in the Experiment A-17 data processing system is logged on a tape, chart, or film log sheet (shown in Fig. 5.4) and then placed in a storage library to await the next step in its processing.

RUN NO. 54

LOG SHEET

I. D. OGO I

TYPE - ORBIT TAPE /_/ REAL TIME TAPE /✓/ STORED TIME TAPE /_/

CARD-ORBIT TAPE /_/ TIME ORDERED DATA TAPE /_/

COMPACT DATA TAPE /_/ DISPLAY FILM /_/ ORBIT PLOT /_/

PLOT TAPE /_/ DISPLAY TAPE /_/

SERIAL NO. R-190

DATE RECEIVED 3/9/65

REVOLUTION NO.

DATA - START DATE/TIME 12/09/64 @ 2058Z

END DATE/TIME 12/10/64 @ 0332Z

COMMENTS: LOCATION CUSTODIAN DATE

NO. 6 FILES

D-4007-69

FIG. 5.4 EXAMPLE OF SRI TAPE LOG SHEET

Agiwarn telegrams, ESSA bulletins, and other notices of geophysical events are used to provide card inputs to the Experiment A-17 data processing system. Geophysical event cards are punched showing the occurrence of solar flares, daily sunspot counts, 3-hours magnetic-K indexes, diurnal flux measurements at discrete frequencies, and events associated with VLF measurements.

The processing of the digital experimental and attitude-orbit data from OGO-I is accomplished by a four-pass computer processing system. The first three phases are processed on the Burroughs B-5500 computer and the final phase on the Control Data Corporation (CDC) 160-A computer. The description that follows includes inputs and outputs, the program design, the on-line/off-line printer outputs, the operational procedures, and the application of the inputs and outputs to the total experiment data reduction and processing.

5.2.2 Phase I Processing

The first phase on the B-5500 is the processing of attitude-orbit magnetic tape data along with associated command and geophysical event cards. The system block diagram of Phase I is shown in Fig. 5.5. The inputs and outputs of the first phase are:

Inputs	Outputs
(1) Attitude-orbit tape	(1) Collated card-orbit tape (CAOR)
(2) Command cards	(2) Orbital ephemeris
(3) Geophysical event cards	(3) Cal-Comp orbital plot tape (optional)

The input attitude-orbit tapes are multi-file compilations of attitude and orbital parameters. The format for the attitude-orbit tapes has been given in the previous section (see Table 5.7). Each file contains information on a single revolution of the satellite around the earth. Attitude-orbit files are separated by end-of-file markers. The attitude and orbital parameters are given at 1-minute increments throughout the entire revolution. There are usually one to four files per orbit tape, with approximately 3840 complete records per file.

The command cards from NASA or cards key-punched by SRI personnel from operations information are integrated with the geophysical event cards into the time-ordered deck which is used as an input to the first computer phase. This integrated card deck covers the exact time span of the corresponding attitude-orbit information.

Another aspect of the CAOR routine is the frequency of data selection from the attitude-orbit tape. Since the orbit of OGO-I is highly eccentric, the satellite velocity varies over an extensive range from approximately 10 km/s at perigee to approximately 0.5 km/s at apogee. Therefore it is not necessary to include all the available 1-minute attitude-orbit data computations on the CAOR tape when the satellite is traveling at its slower speeds. The sampling rate at which data are selected from the attitude-orbit tape is determined by the total velocity of the satellite. The rates at which data are sampled are given in Table 5.8.

Table 5.8

ORBIT DATA-SAMPLING RATE VERSUS SATELLITE VELOCITY

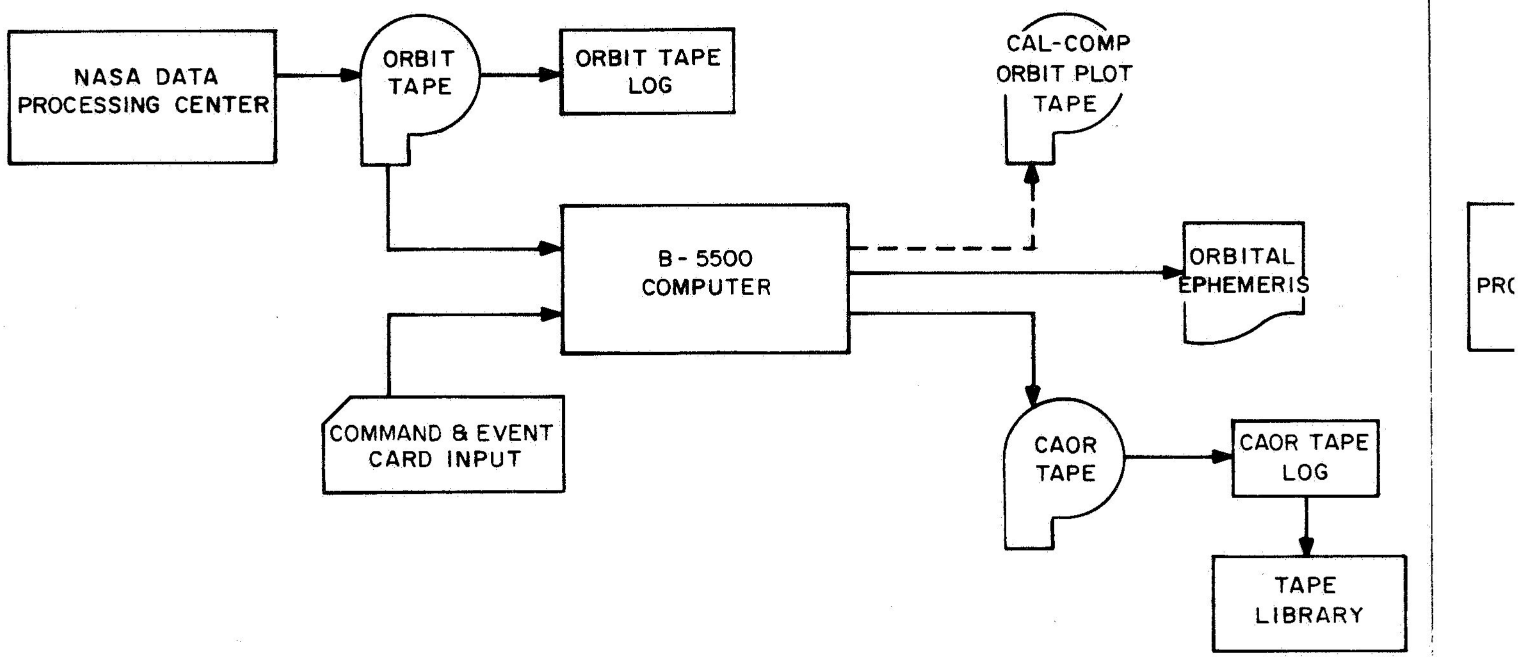
Orbit Data-Sampling Rate (min)	Satellite Velocity (km/s)
1	≥7.00
2	5.00 → 6.99
4	3.00 → 4.99
8	2.00 → 2.99
16	1.00 → 1.99
32	≥0.99

The CAOR tape, which is a permanent library tape, is the primary source of attitude-orbit and card information for each revolution. It is an input tape in the third-phase computer processing; then the parameters on it are merged with the associated time-ordered experimental data records.

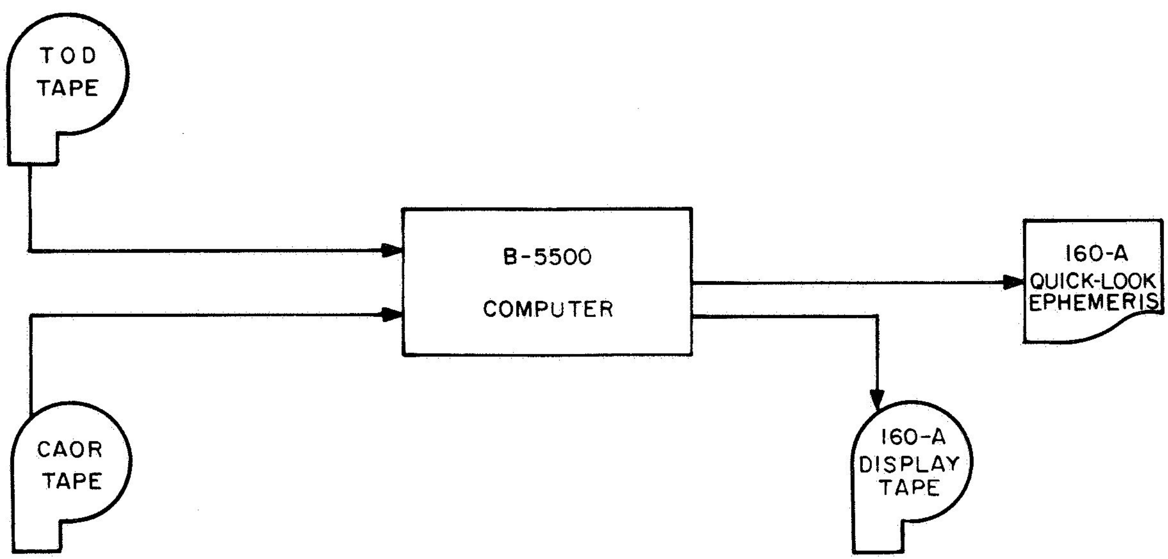
The second output of the first phase is the CAOR ephemeris. The ephemeris prints out, on line, each data record of the CAOR tape, along with the commands for Experiments A-17 and A-14.* The parameters

*Experiment A-14 has been found to interfere with our experiment. It is therefore necessary to flag the times when it is operating.

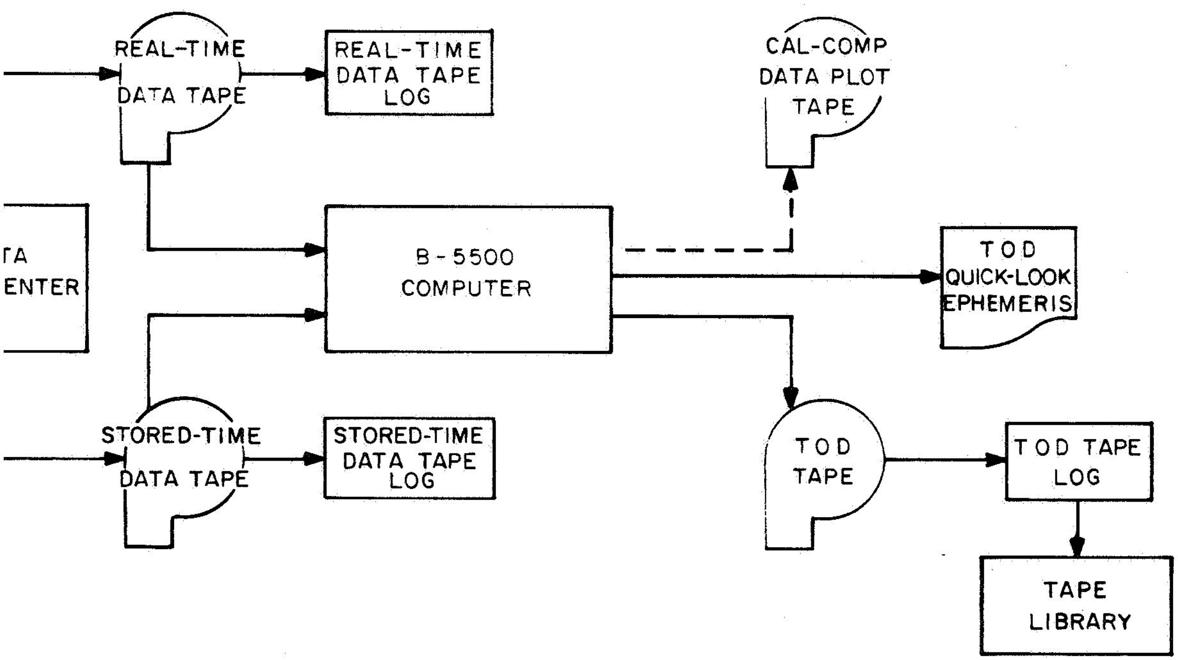
FIRST COMPUTER PHASE



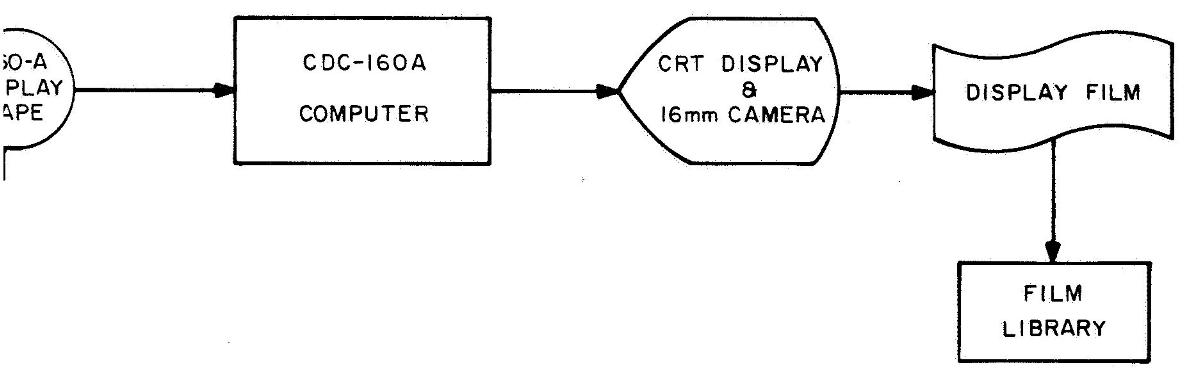
THIRD COMPUTER PHASE



SECOND COMPUTER PHASE



FOURTH COMPUTER PHASE



D-5915-IR

FIG. 5.5 SRI OGO-I DIGITAL DATA-PROCESSING SYSTEM selected from the NASA orbit tapes and stored on the CAOR tapes, as well as all the geophysical event information for each revolution, are also included in the ephemeris printout. The columns, data forms, labels and functions for the ephemeris format appear on Table 5.9. An example of the ephemeris printout appears as Fig. 5.6.

An optional third output from the first phase is a CAOR Cal-Comp plot tape. The following selected attitude-orbit parameters are plotted:

(1) Altitude above surface of earth
(2) McIlwain L parameter
(3) Gyrofrequency at satellite
(4) Minimal gyrofrequency along the field line
(5) Local mean time at the subsatellite point
(6) Geographic latitude
(7) Geographic longitude
(8) Magnetic latitude
(9) SEP angle.

The geophysical events, as well as the commands for Experiments A-17 and A-14 are also indicated.

An example of the CAOR plot form, a Cal-Comp tape, is shown in Fig. 5.7.

5.2.3 Phase II Processing

The second phase of the digital data processing is the processing on the B-5500 of real-time and stored digital experimental magnetic data tape. The block diagram of Phase II is shown in Fig. 5.5. The inputs and outputs of the second phase are:

Inputs	Outputs
(1) Real-time data tape	(1) Time-ordered data (TOD) tape
(2) Stored-time data tape	(2) TOD quick-look printout
	(3) Cal-Comp data plot tape (optional)

Approximately 95 percent of the Experiment A-17 data (the total bits of information) are recorded on real-time decommutation

Table 5.9

EXPERIMENT A-17 CAOR EPHEMERIS FORMAT

Columns	Label	Identification
1-4	MMDD	Month, day (UT)
6-9	HHMM	Hour, minute (UT)
11-16	ALT KM	Altitude above surface of earth
18-22	LAT N	Subsatellite geographic latitude
24-27	LONG E	Subsatellite geographic longitude
29-32	DIST RE	Distance from center of earth in earth radii
34-36	SEP	Sun-earth-probe angle
39-42	VT KM/S	Total velocity
44-48	VR KM/S	Radial velocity
50-54	VB KM/S	Velocity along magnetic field
57-58	SZ	Spin-earth angle, 0-180°
60-61	SB	Spin-magnetic-field angle, 0-90°
63-67	M LAT	Magnetic latitude
69-73	L	McIlwain L parameter
75-81	FH KHZ	Gyrofrequency at satellite
83-89	FHO KHZ	Minimum gyrofrequency on field line
91-92	LAT N	Geographic latitude, northern ingress point
94-95	LGN N	Geographic longitude, northern ingress point
96-97	ZA N	Zenith angle, northern ingress point
100-101	LAT S	Geographic latitude, southern egress point
103-104	LGN S	Geographic longitude, southern egress point
105-107	ZA S	Zenith angle, southern egress point
109-112	LMT HR	Subsatellite local mean time

MMDD	HHMM	ALT KM	LAT N	LONG E	DIST RE	SEP	VT KM/S	VR KM/S	VB KM/S	SZ	SB	M LAT	L	FH KC	FHO KC	LAT N	LGN N	ZA N	LAT S	LGN S	ZA S	LMT HR
526	2159	55104	-8.4	124.1	9.7	89	2.84	-2.42	-2.14	65	74	-19.6	10.80	1.140	0.694	0	0	-36	0	0	-36	6.3
526	2207	53936	-8.9	122.6	9.5	89	2.88	-2.45	-2.20	65	74	-20.1	10.66	1.215	0.722	0	0	-34	0	0	-34	6.3
526	2215	52751	-9.3	121.1	9.3	88	2.93	-2.49	-2.25	64	73	-20.6	10.52	1.297	0.751	0	0	-33	0	0	-33	6.3
526	2223	51550	-9.8	119.7	9.1	88	2.98	-2.52	-2.31	63	73	-21.1	10.37	1.389	0.783	0	0	-31	0	0	-31	6.4
526	2231	50331	-10.3	118.3	8.9	87	3.03	-2.56	-2.37	63	72	-21.7	10.23	1.490	0.818	0	0	-30	0	0	-30	6.4
526	2235	49715	-10.5	117.6	8.8	87	3.05	-2.58	-2.40	63	72	-21.9	10.15	1.545	0.836	0	0	-29	0	0	-29	6.4
526	2239	49094	-10.8	116.9	8.7	87	3.08	-2.60	-2.44	62	71	-22.2	10.08	1.603	0.855	0	0	-29	0	0	-29	6.4
526	2243	48469	-11.1	116.2	8.6	87	3.10	-2.62	-2.47	62	71	-22.5	10.00	1.665	0.874	0	0	-28	0	0	-28	6.5
526	2247	47839	-11.3	115.6	8.5	87	3.13	-2.64	-2.50	62	71	-22.8	9.93	1.730	0.894	0	0	-27	0	0	-27	6.5
526	2251	47204	-11.6	114.9	8.4	87	3.16	-2.66	-2.53	61	70	-23.1	9.85	1.799	0.914	0	0	-27	0	0	-27	6.5
526	2255	46564	-11.9	114.2	8.3	86	3.19	-2.68	-2.57	61	70	-23.3	9.77	1.872	0.936	0	0	-26	0	0	-26	6.5
526	2259	45920	-12.2	113.6	8.2	86	3.22	-2.70	-2.60	61	69	-23.6	9.70	1.949	0.959	0	0	-26	0	0	-26	6.6
526	2303	45270	-12.5	113.0	8.1	86	3.25	-2.72	-2.64	60	69	-23.9	9.62	2.032	0.982	0	0	-25	0	0	-25	6.6
526	2307	44615	-12.8	112.3	8.0	86	3.28	-2.74	-2.67	60	69	-24.3	9.54	2.119	1.006	0	0	-24	0	0	-24	6.6
526	2311	43955	-13.1	111.7	7.9	85	3.31	-2.76	-2.71	59	68	-24.6	9.46	2.213	1.032	0	0	-24	0	0	-24	6.6
526	2315	43290	-13.4	111.1	7.8	85	3.34	-2.78	-2.74	59	68	-24.9	9.38	2.313	1.058	0	0	-24	0	0	-24	6.7
526	2319	42620	-13.7	110.5	7.7	85	3.37	-2.81	-2.78	59	67	-25.2	9.30	2.419	1.085	0	0	-23	0	0	-23	6.7
526	2323	41944	-14.0	110.0	7.6	85	3.40	-2.83	-2.82	58	67	-25.5	9.23	2.533	1.113	0	0	-23	0	0	-23	6.7
526	2327	41262	-14.4	109.4	7.5	84	3.44	-2.85	-2.86	58	66	-25.9	9.15	2.655	1.142	0	0	-22	0	0	-22	6.7
526	2331	40575	-14.7	108.9	7.4	84	3.47	-2.88	-2.89	57	65	-26.2	9.07	2.786	1.173	0	0	-22	0	0	-22	6.8
526	2335	39882	-15.1	108.3	7.3	84	3.51	-2.90	-2.93	57	65	-26.6	8.99	2.927	1.204	77	109	55	-56	115	89	6.8
526	2339	39183	-15.5	107.8	7.2	84	3.55	-2.93	-2.97	57	64	-26.9	8.91	3.079	1.237	77	108	55	-56	115	89	6.8
526	2343	38479	-15.8	107.3	7.0	83	3.59	-2.95	-3.02	56	64	-27.3	8.83	3.242	1.271	77	108	54	-56	115	88	6.9
526	2347	37768	-16.2	106.8	6.9	83	3.63	-2.98	-3.06	56	63	-27.7	8.75	3.419	1.306	77	107	54	-56	114	87	6.9
526	2351	37051	-16.6	106.4	6.8	83	3.67	-3.00	-3.10	55	62	-28.1	8.67	3.610	1.343	77	106	54	-56	114	87	6.9
526	2355	36328	-17.1	105.9	6.7	82	3.71	-3.03	-3.14	55	61	-28.5	8.59	3.817	1.381	76	106	53	-56	114	86	7.0
526	2359	35598	-17.5	105.5	6.6	82	3.75	-3.05	-3.19	54	61	-28.9	8.51	4.043	1.421	76	105	53	-55	113	86	7.0
	0 0	0 UMAGA	K3			0		0	31	S49A												
	0 0	0 USSPO	SS611			0		0	40	S49A												
527	0003	34862	-17.9	105.1	6.5	82	3.80	-3.08	-3.23	54	60	-29.4	8.43	4.288	1.461	76	104	53	-55	113	85	7.1
527	0007	34119	-18.4	104.7	6.4	81	3.84	-3.11	-3.28	53	59	-29.8	8.35	4.555	1.503	76	104	52	-55	113	84	7.1
527	0011	33370	-18.8	104.4	6.2	81	3.89	-3.14	-3.32	53	58	-30.3	8.27	4.847	1.547	76	103	52	-55	112	84	7.1
527	0015	32614	-19.3	104.1	6.1	81	3.94	-3.17	-3.37	52	57	-30.7	8.19	5.168	1.592	76	103	51	-55	112	83	7.2
527	0019	31850	-19.8	103.8	6.0	80	3.99	-3.20	-3.42	52	56	-31.2	8.11	5.520	1.638	76	102	50	-55	112	82	7.2
527	0023	31080	-20.3	103.6	5.9	80	4.05	-3.23	-3.46	51	55	-31.8	8.03	5.907	1.686	76	102	50	-55	112	82	7.3
527	0027	30303	-20.9	103.4	5.8	80	4.10	-3.26	-3.51	50	54	-32.3	7.96	6.336	1.735	75	102	49	-55	112	81	7.3
527	0031	29518	-21.4	103.2	5.6	79	4.16	-3.29	-3.56	50	53	-32.8	7.88	6.810	1.784	75	101	48	-55	111	80	7.4
527	0035	28726	-22.0	103.1	5.5	79	4.22	-3.32	-3.61	49	52	-33.4	7.81	7.337	1.835	75	101	47	-55	111	80	7.5
527	0039	27926	-22.6	103.0	5.4	78	4.28	-3.35	-3.66	48	51	-34.0	7.74	7.925	1.887	75	101	46	-55	111	79	7.5
527	0043	27119	-23.2	103.0	5.3	78	4.35	-3.38	-3.71	48	49	-34.6	7.67	8.581	1.939	75	101	45	-55	111	78	7.6
527	0047	26304	-23.9	103.0	5.1	77	4.41	-3.41	-3.76	47	48	-35.3	7.60	9.318	1.992	75	101	44	-54	111	77	7.6
527	0051	25482	-24.6	103.1	5.0	77	4.49	-3.44	-3.81	46	47	-36.0	7.53	10.148	2.045	75	101	43	-54	111	76	7.7
527	0055	24652	-25.3	103.3	4.9	76	4.56	-3.48	-3.85	45	45	-36.7	7.47	11.086	2.097	75	101	41	-54	111	76	7.8
527	0059	23814	-26.0	103.5	4.7	76	4.64	-3.51	-3.90	45	43	-37.4	7.41	12.150	2.148	75	101	40	-54	111	75	7.9

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FIG. 5.6 EXAMPLE OF A CAOR EPHEMERIS PRINTOUT data tapes. Real-time data tapes are multi-file tapes, a file consisting of contiguous data at a uniform bit rate. The maximum number of records per file is approximately 360 records at high bit rate (HBR), 180 records at medium bit rate (MBR), and 45 records at low bit rate (LBR). The number of files per data tape varies from one to six. The format for Experiment A-17 data files has been given in the previous section (see Tables 5.6 and 5.7).

The second type of input to the second-pass B-5500 processing is the stored-time decommutated data tapes, which have the same data format as the real-time experimental data tapes. The stored experimental data are recorded at 1 kb/s, as in the case of LBR data. In order to differentiate LBR real-time data from LBR stored-time data, the latter are referred to as stored-bit rate (SBR) data. The stored data are useful only when real-time transmissions are not being made. Stored experimental data are used to extend the data coverage to portions of the orbit where real-time data cannot be received. Timing errors in the recording of stored data have made their use unreliable.

The primary output of the second phase of computer processing is the TOD tape, permanent library tape containing all the real- and stored-time experimental data in calibrated contiguous files. By computer processing the experimental data are compacted on the TOD tapes--resulting in about one-fifth as many tapes as NASA sent. The TOD program includes the following work on each experimental data tape:

(1) Each data point is transferred into a calibration and position TOD array, giving the magnitude of the magnetic flux density in units of decibels with respect to 1 gamma rms. (See Sec. 2.3.)

(2) Real- and stored-time experimental data files are ordered sequentially.

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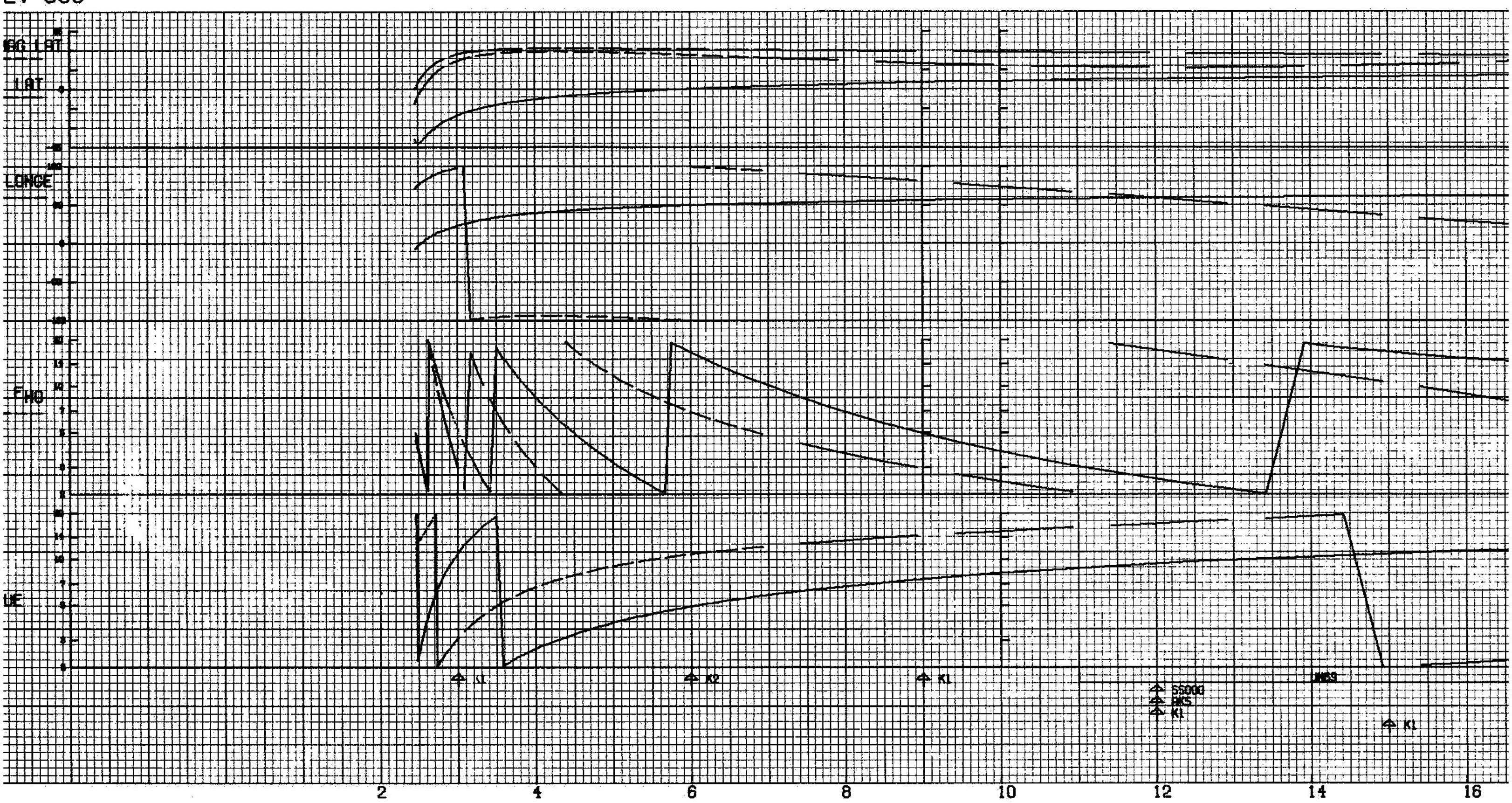

AVG LAT
LAT
LONGE
FHO
UE
K1
K2
K1
55000
DKS
K1
DKS
K1
2
4
6
8
10
12
14
16

67

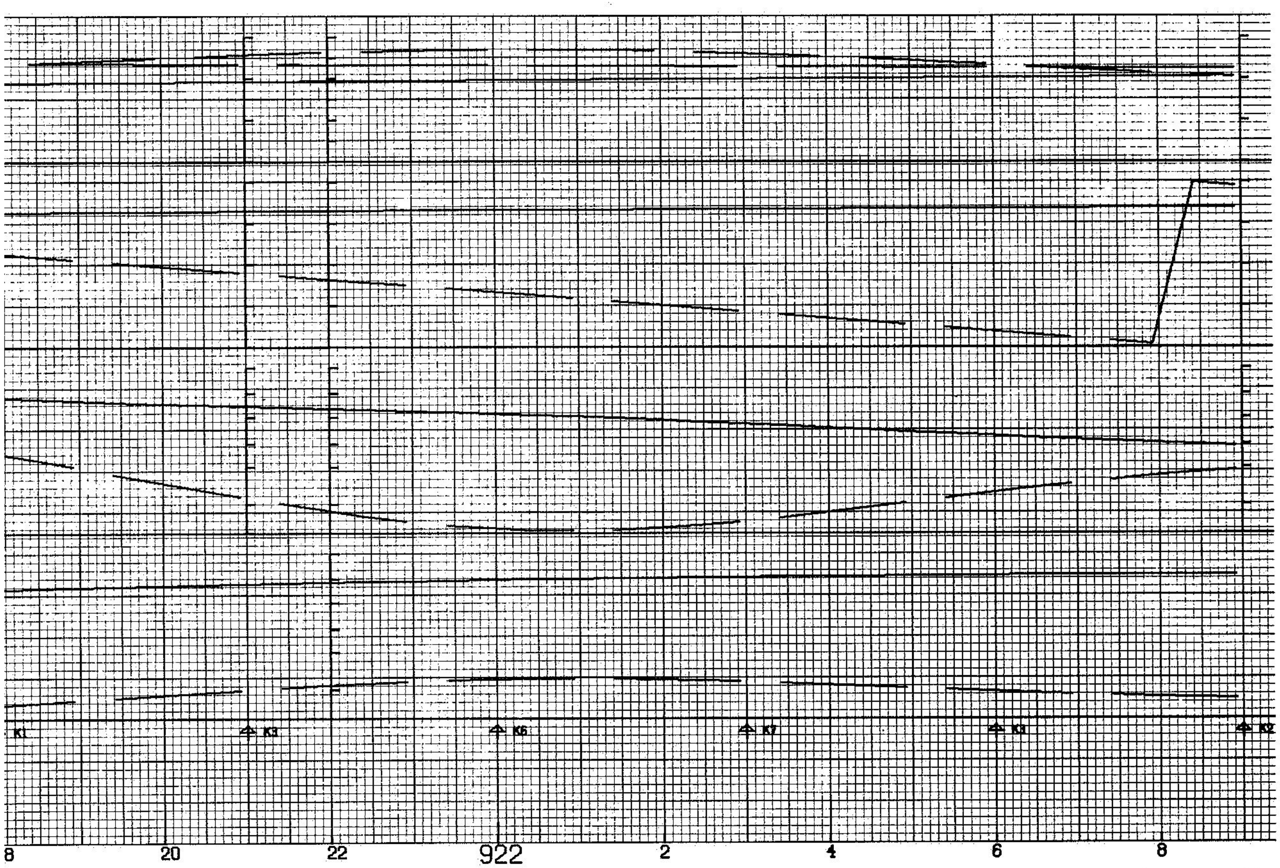

FIG. 5.7 EXAMPLE OF A CAL-COMP CAOR PLOT

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(3) New TOD files are created whenever a bit-rate or mode change occurs (either experiment or spacecraft). For example, in a normal case, an experimental data file contains a change in experiment mode from sweep-frequency to the fixed-frequency mode. This mode change causes a new TOD file to be generated at the point of the switching. The TOD files are separated by end-of-file markers. An extended loss of synchronization in the sweep-frequency mode causes a new data file to be created, even though the experiment had not really changed from sweep-frequency to fixed-frequency mode.

The format of the TOD tape label record is given in Table 5.10 and that of the TOD tape data record is given in Table 5.11. These formats can be compared with the NASA data tape formats given in Tables 5.5 and 5.6. The first record per file is a label record. It serves as a means of identifying the data contained on this to the file of which it is part. Each label record contains 72 6-bit characters. All fields of characters are binary integers, except where noted.

Each data record contains three logical data records. All logical records are 2432 6-bit characters long. The physical record is three times 2432 6-bit characters long. All fields of data are in binary integer form unless otherwise specified.

Table 5.10

TOD LABEL RECORD FORMAT

Characters	Identification
1-8	Start time of data--day of year
9-16	Start time of data--milliseconds of day
17-24	Mode: 0 = fixed 1 = sweep
25-32	Bit rate: 0 = low 1 = medium 2 = high 3 = low, stored
33-40	Bit rate time 1152 ms = low 144 ms = medium 18 ms = high
41-48	Run number
49-50	BCD blanks
51-55	BCD characters S-49A
56	BCD blank
57-64	File number
65-72	Data type 1 = real-time data 2 = stored-time data

Table 5.11

TOD DATA RECORD FORMAT

Characters	Identification
1-8	Day of year
9-16	Start of data
17-24	End of data
25-32	Accumulated time start
33-40	Accumulated time end
41-42	Data quality flag 0 = good 1 = bad
43-48	Total error count
49-52	Mode 0 = fixed 1 = sweep
53-56	Total fill data flags
57-64	Characters 9-10*
65-72	Characters 13-14*
73-80	Band I static frequency times 100
81-88	Band II static frequency times 100
89-96	Band III static frequency times 100
97-104	Characters 3-8*
105-108	Characters 11-12*
109-112	Characters 15-18*
113-116	Characters 19-20*
117-120	Characters 21-24*
121-125	Characters 25-26*
126-128	Characters 27-30*
129-130	Blank
131-132	Band I amplitude } One data point
133-134	Band II amplitude } One data point
135-136	Band III amplitude } One data point
137-2176	There are 255 8-character fields filled as the 8-character field of Characters 129-136.
2177-2178	Fill data or error flag 0 = no fill data or error 1 = fill data or error
2179-2432	There are 127 2-character fields filled as the 2-character field of Characters 2177 and 2178. There is one fill-data or error flag for two data points.

*Of original NASA data tape.

The TOD tape becomes an input into the third phase of computer processing, along with CAOR tape.

Another output of the second phase is the TOD quick-look log sheet, an on-line printer output of selected information from the TOD tape. This printout, generated for each TOD tape, records the following information:

(1) The start and stop times of each file

(2) The number of records processed for each file

(3) The transmission data rate for each file

(4) The experiment mode for each file

(5) The total number of records from each file of the NASA data tapes

(6) The tape and file numbers of the NASA tapes

(7) The total number of new TOD files generated.

An example of the TOD quick-look printout appears as Fig. 5.8. An optional third output from the second phase is a Cal-Comp TOD plot tape. The Cal-Comp TOD plot in Fig. 5.9 shows calibrated amplitude in decibels below 1γ versus frequency for all three bands. The date, time, bit rate, and experiment mode appear in the character test. Like the CAOR program, the TOD program has two versions: one with and one without a Cal-Comp plot package.

5.2.4 Phase III Processing

The third and final phase of the digital data processing system on the B-5500 is the production of a display tape for the CDC 160-A computer. The block diagram of Phase III is shown in Fig. 5.5. The inputs and outputs of the third phase are:

Inputs	Outputs
(1) Card-orbit tape (CAOR)	(1) CDC 160-A tape
(2) Time-ordered data tape (TOD)	(2) 160-A quick-look printout.

```
THIS IS SECTIONOK     0    69   138     6     1     3
                                                        END      5/29   23/45/11   182
  END OF FILE  2 FROM REAL TIME TAPE R405
              5/29  23/44/42   149/85482810
             NUMBER OF RECORDS =  181
START OF FILE  3 FROM REAL TIME TAPE R405
              5/29  23/43/48   149/85428000
                               BIT RATE = 1
                                                          REAL TIME IS 150
                                                         STORED TIME IS 999
                                                        START    5/29   23/43/47    81     1     1    27
THIS IS SECTIONOK     0    69   138     6     1     3
                                                        END      5/30    0/37/42   176
  END OF FILE  3 FROM REAL TIME TAPE R405
              5/30    0/37/14    150/ 2234680
             NUMBER OF RECORDS =  175
START OF FILE  4 FROM REAL TIME TAPE R405
              5/30    1/ 0/18    150/ 3618000
                               BIT RATE = 1
                                                          REAL TIME IS 150
                                                         STORED TIME IS 999
                                                        START    5/30    1/ 0/18    81     1     1    28
THIS IS SECTIONOK     0    69   138     6     1     3
                                                        END      5/30    1/18/40    33
                                                          REAL TIME IS 150
                                                         STORED TIME IS 999
```

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FIG. 5.8 EXAMPLE OF A TOD QUICK-LOOK PRINTOUT

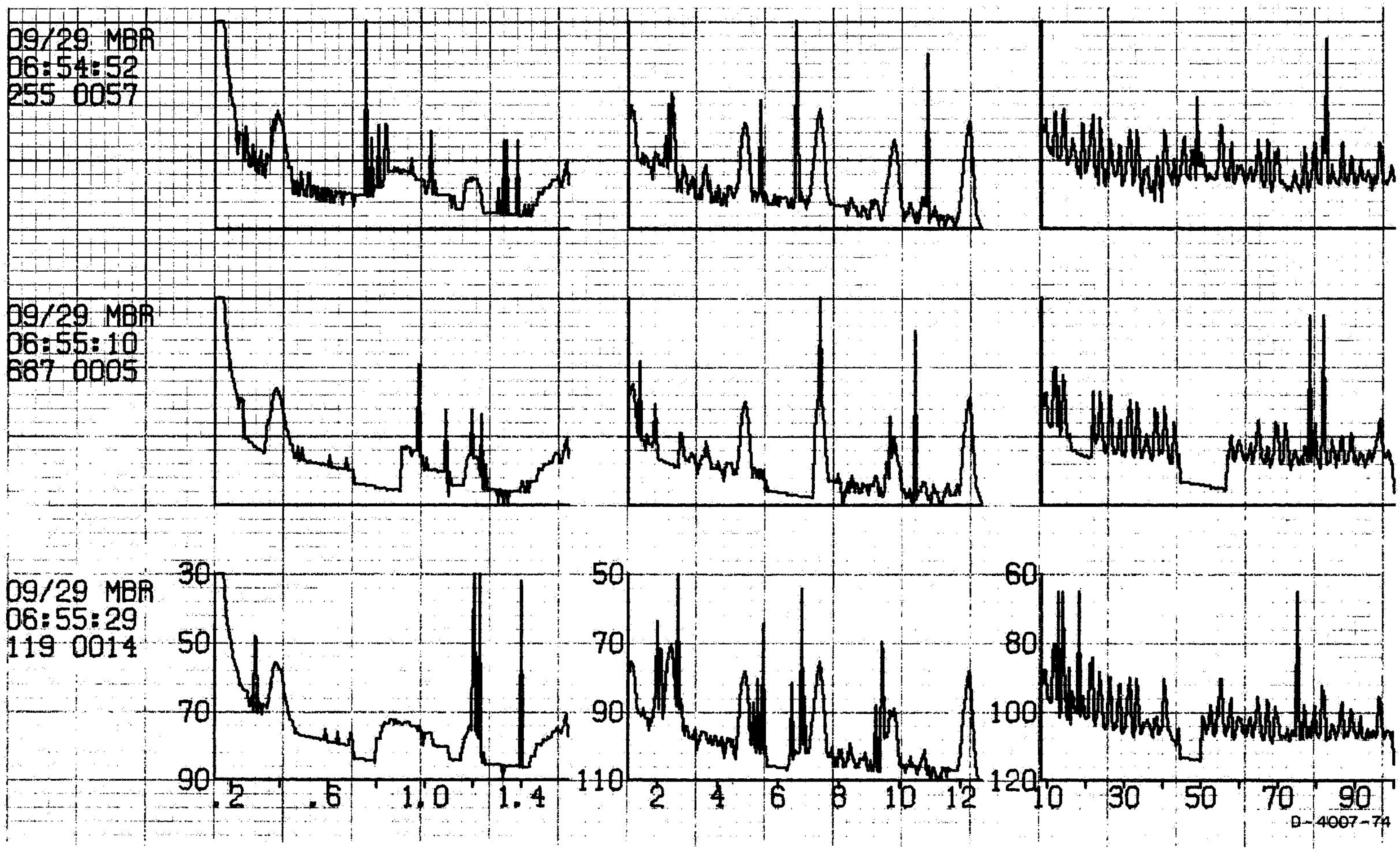

FIG. 5.9 EXAMPLE OF A CAL-COMP TOD PLOT

The two inputs used in the third phase are the CAOR and TOD library tapes. The intent here is to integrate experimental data with the associated time-ordered attitude-orbit parameters, thereby producing an output plot tape containing the information from both input tapes. However, not all the attitude-orbit and card parameters are written on the 160-A output tape. The selected CAOR tape parameters written on each output 160-A record are:

(1) Local mean time of the subsatellite point
(2) Sun (SUN) or eclipse (ECL)
(3) Geographic latitude
(4) Geographic longitude
(5) SEP angle
(6) Altitude above earth's surface
(7) McIlwain L parameter
(8) Magnetic latitude
(9) Gyrofrequency at the satellite
(10) Minimum gyrofrequency along the field line
(11) 3-hour magnetic K index (Fredericksburg, Md.)
(12) Sunspot number
(13) Solar flare (plus duration)
(14) An indicator flag for Experiment A-14 having been on.

A 160-A tape contains exactly the same number of records as does the TOD tape from which it was made. Time-ordered data tape files are identical to 160-A tape files, separated by end-of-file markers.

The TOD and CAOR input tapes are combined in the B-5500 computer. The third-phase program searches the TOD tape until it finds a date and time that lie within the date-time range of the first revolution on the CAOR tape. If the time of the first frame of data on the TOD record falls between the first and the second records of the CAOR tape, that TOD record is processed with the parameters of the first record of the CAOR tape. The succeeding records of the TOD tape are processed with the parameters of the first CAOR record until the start time of a TOD record exceeds the start time of the next CAOR record. The third phase does not provide interpolation between CAOR parameter outputs; therefore, at times many TOD tape records have identical associated parameters.

The third phase is controlled by the CAOR tape. Only the records on the TOD tape falling between the start time of the first record and the end of file on the CAOR tape are processed for a particular revolution. The TOD records extending beyond the end of the revolution being processed are processed in a subsequent run. The maximum number of TOD records processed for a single revolution is about 6200. Even though multiple TOD records are associated with a single CAOR record, the times generated on the 160-A tape records are identical to those of the TOD records.

The second output from the third phase is a printout of information written on the 160-A output tape. This printout, shown in Fig. 5.10, is generated for all 160-A output tapes. It is valuable in the pre-editing of the information on the 160-A tape displayed during the final phase of processing on the 160-A computer. The information generated on the 160-A quick-look printout is:

(1) Revolution number

(2) Start and end time of revolution

(3) Start and end time of each 160-A tape data file

(4) Bit rate, mode, and whether the data are real- or stored-time for each data file

(5) Start- and end-of-file record numbers.

5.2.5 Phase IV Processing

The fourth and final phase of the data processing system uses the 160-A display tape generated during the third pass of the B-5500 processing. The 160-A computer displays the information contained on the tape on a cathode-ray tube (CRT) while 16-mm photographs are taken of the displayed data. The data from the display tape are recorded

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```
     BIT RATE 0   MODE 1   STORED/REAL 1
START TIME  10/27   0/37/42PIC NO. 2961
END   TIME  10/27   2/23/22   PIC NO. 3004

     BIT RATE 0   MODE 1   STORED/REAL 1
START TIME  10/27   2/28/17PIC NO. 3005
END   TIME  10/27   4/13/58   PIC NO. 3048

     BIT RATE 0   MODE 1   STORED/REAL 1
START TIME  10/27   4/18/53PIC NO. 3049
END   TIME  10/27   5/39/59   PIC NO. 3082

     BIT RATE 0   MODE 1   STORED/REAL 1
START TIME  10/27  18/46/25PIC NO. 3083
END   TIME  10/27  20/32/ 5   PIC NO. 3125

     BIT RATE 0   MODE 1   STORED/REAL 1
START TIME  10/27  22/27/36PIC NO. 3126
END   TIME  10/28   0/13/16   PIC NO. 3168
```

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FIG. 5.10 EXAMPLE OF A CDC 160-A QUICK-LOOK PRINTOUT in time sequence on film, thus producing a movie. This display film becomes the final library record of the SRI data processing system; it enables project personnel to store and examine conveniently a large quantity of data off-line from the computer. The block diagram of Phase IV is shown in Fig. 5.5. The inputs and outputs of the fourth phase are:

Inputs	Outputs
(1) CDC 160-A display tape	(1) CDC 160-A display film
(2) Manual keyboard commands and controls	(2) Real-time checking and monitoring of output.

The input 160-A tape contains all the experimental data plus the selected CAOR tape parameters in a format compatible with the specifications of the fourth-phase CDC 160-A program. Records on the 160-A input tape are read into core storage one at a time. The computer, however, has the capability of handling simultaneously three data records. While the first record is being called out to be displayed on the CRT, the third is being read into memory. An example of this overlapping of input and output is shown in Fig. 5.11. The format of the 160-A data block (Table 5.12), the format of the graph coordinates in the data block (Table 5.13), and the format of the signature block (Table 5.14) are presented subsequently.

The graph coordinates are organized in 32 segments, each segment containing 58 characters on tape. Each segment represents the points to be displayed within a vertical strip, which is 1/32 of the total horizontal extent of the graph. The characters in each segment are ordered as in Table 5.13.

A point specification is made up of two characters, i.e., four octal digits. The horizontal coordinate component in a point specification is the 3 least significant bits; the vertical coordinate component is the 9 most significant bits. The vertical position within the graph is the sum of the value of the vertical coordinate (truncated, with round-off, to 7 bits) and of the vertical height of the base of the graph.

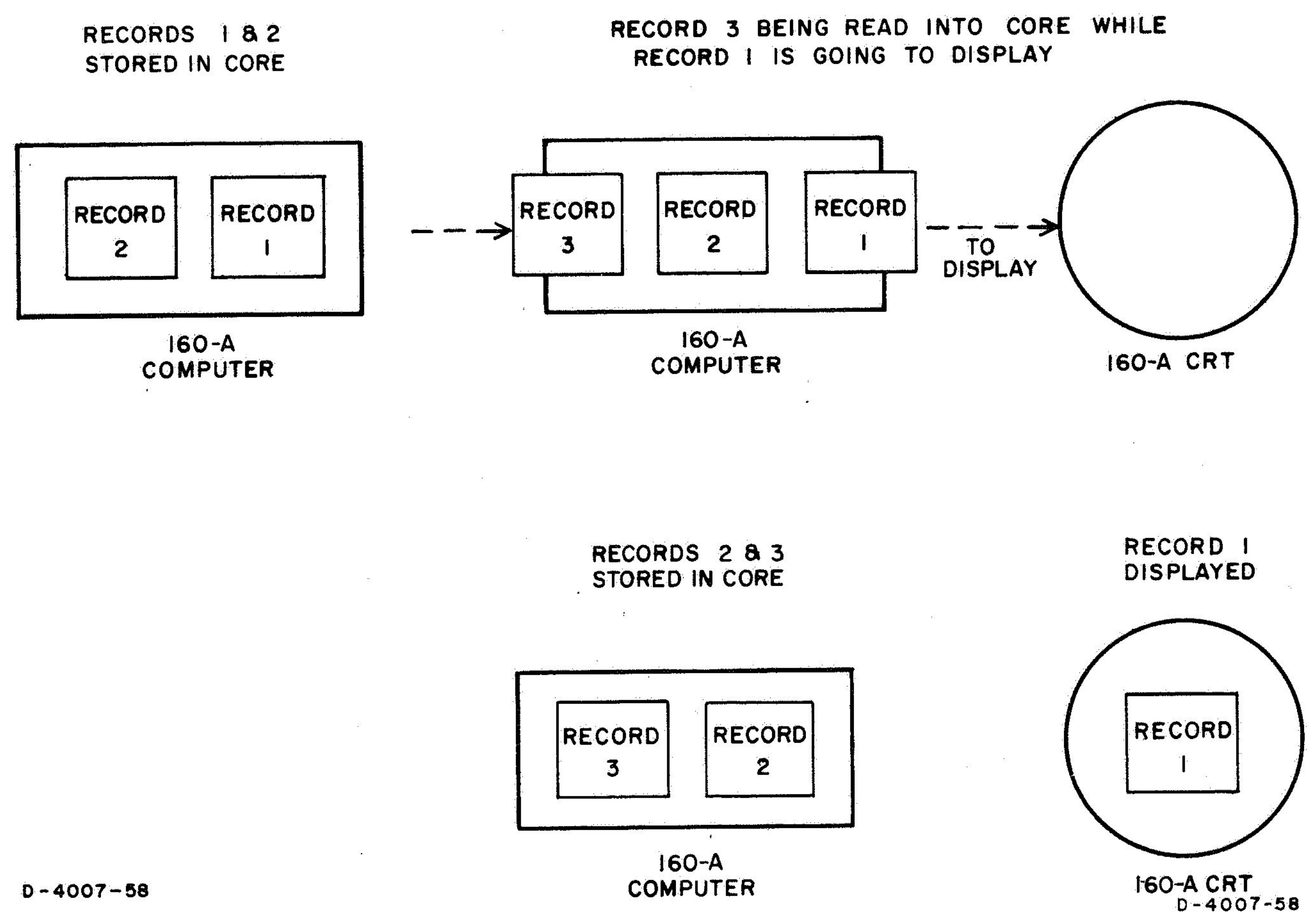


FIG. 5.11 CDC 160-A INPUT-OUTPUT SEQUENCE

Table 5.12

FORMAT OF CDC 160-A DATA BLOCK

Characters	Contents
1-8	Experiment name
14-16	Orbit number
20-24	Frame number (film frame)
25-26	Year
28-29	Month
31-32	Day
33-34	Hours
36-37	Minutes
39-40	Seconds
41-43	Local mean time, hours and tenths of hours
45	Sun indicator
46	Magnetic pole indicator
48-50	Satellite illumination, either Sun (SUN) or eclipse (ECL)
53	Bit rate
62-64	Solar zenith angle
67-72	Altitude
78-80	Magnetic latitude
81-88	Gyrofrequency at satellite
94-96	Latitude (e.g., 29N)
101-104	Longitude (e.g., 55E)
105	Real-time/stored-time indicator
106	7090 to B5500 tape parity indicator
107	Sweep/static indicator
113-116	Frequency for top graph
117-120	Frequency for middle graph
121-124	Frequency for bottom graph
125-126	Satellite position horizontal, left ellipse
127-128	Satellite position vertical, left ellipse
129-130	As 125, 126, right ellipse
131-132	As 127, 128, right ellipse
133	Magnetic k index
134-136	Sunspot number
138-140	Time after or before next flare
141-144	Gyrofrequency indicator on graph
146-148	Millisecond of day
149-150	Angle of spin vector with respect to magnetic field lines
151-156	Special message to be displayed at the right-hand side of Line 6 of the text
157-158	Flare class
159-160	Total error count
161-164	L parameter
165-172	FHO*
173-176	FHO Indicator
177	North Pole indicator
178	14 if Experiment 14 is on, 0 if it is off
201-258	Graph coordinates, Segment 1 (see Table 5.11)
259-316	Graph coordinates, Segment 2
⋮	⋮
1999-2056	Graph coordinates, Segment 32

*Minimum electron gyrofrequency along the field line through the satellite.

Table 5.13

FORMAT OF GRAPH COORDINATES IN DATA BLOCK

Character Position in Segment	Contents*
1	Segment number + 4 (04_8 - 43_8)
2	04 (constant for all segments)
3-4	Point specification† of top graph = Ti
5-6	Point specification† of middle graph = Mi
7-8	Point specification† of bottom graph = Bi
9-10	Next point specification of top graph = Ti + 1
11-12	Next point specification of middle graph = Mi + 1
13-14	Next point specification of bottom graph = Bi + 1
15-16	Good/bad telemetry indicator (first pair of points)
17-18	Point Specification = Ti + 2
⋮	⋮ ⋮
55-56	Last point specification = Bi + 7
57-58	Good/bad telemetry indicator (fourth pair of points)

*In octal.

†A point specification is a combination of the vertical and horizontal coordinates of the point to be displayed.

Table 5.14

FORMAT OF SIGNATURE BLOCK

Characters	Contents
1-32	Spare
33-104	Horizontal coordinates of points on first orbit
105-176	Vertical coordinates of points on first orbit
177-320	As 33-176, but for second orbit
320-2056	Spare

The vertical heights of the bases of the three graphs are:

540 - Top graph

300 - Middle graph

040 - Bottom graph.

The good/bad telemetry indicator for each pair of points (per graph) is 000x if good and 020x where:

x = 1 per first pair of points

x = 3 per second pair of points

x = 5 per third pair of points

x = 7 per fourth pair of points.

The 160-A tape records, upon program initiation, are displayed one record at a time on the 160-A CRT display. The output from three receivers in the experiment appears on three graphs: The top graph on the display is Band 1 (0.200 to 1.6 kHz); the middle graph is Band 2 (1.6 to 12.5 kHz); and the bottom graph is Band 3 (12.5 to 100 kHz). When the receiver is commanded into the sweep-frequency mode, all graphs display magnetic-flux density amplitude (in decibels below 1γ) versus frequency (in kilohertz). In the fixed-frequency mode, all graphs display amplitude versus time. There are 256 data words per band, therefore 768 words are presented on each frame of film (not to be confused with the frame of main commutator data). The data words in each band are time contiguous with one another as the receivers step from one end of their bands to the other. The time displayed in the upper right-hand corner of the film is the time of the first bit of the first word of Main Commutator Word 1 of the telemetry main frame from which the data originated.

Associated with the experimental data are two orbital ellipses and nine lines of character text. The left-hand ellipse is a polar projection, which gives the position of the satellite with respect to the sun and magnetic North Pole directions. The right-hand ellipse is an equatorial projection showing the line of apsides of the orbit, along with the satellite position and magnetic North Pole direction. The character test gives the satellite identification, revolution number, frame number, date/time, geophysical events, and associated attitude and orbital parameters. A detailed drawing of the display record appears in Fig. 5.12. A print made from a typical 160-A film record is shown in Fig. 5.13.

5.2.6 Output Cine Display System

This subsection of the report has five parts. The first part details the start-up procedure; the second describes the filming of data (Film Mode); the third details the way in which the tape may be scanned to examine the data without filming it (Scan Mode); the fourth describes the way in which the horizontal scales may be changed (Scale Mode); and the fifth is concerned with error conditions.

5.2.6.1 Start-up Procedure

The following sequence of operations should take place:

(1) Switch on the computer, display, tape unit, typewriter, and camera interface equipment.

(2) Select magnetic tape on the buffer channel; select typewriter, display, and Terminal B on the normal channel.

(3) Master clear the computer. Place the program tape in the paper tape reader, load, and run.

(4) Mount data on the tape unit. Go to the load point. Switch the tape unit to No. 1 and high density, and switch the tape control unit to binary (check that the "right enable" ring is absent from data tape).

(5) Master clear, set p = 100, and run. The computer should read one record of tape and display the axes for the three graphs, plus certain dummy information in the text display, plus the satellite orbits.

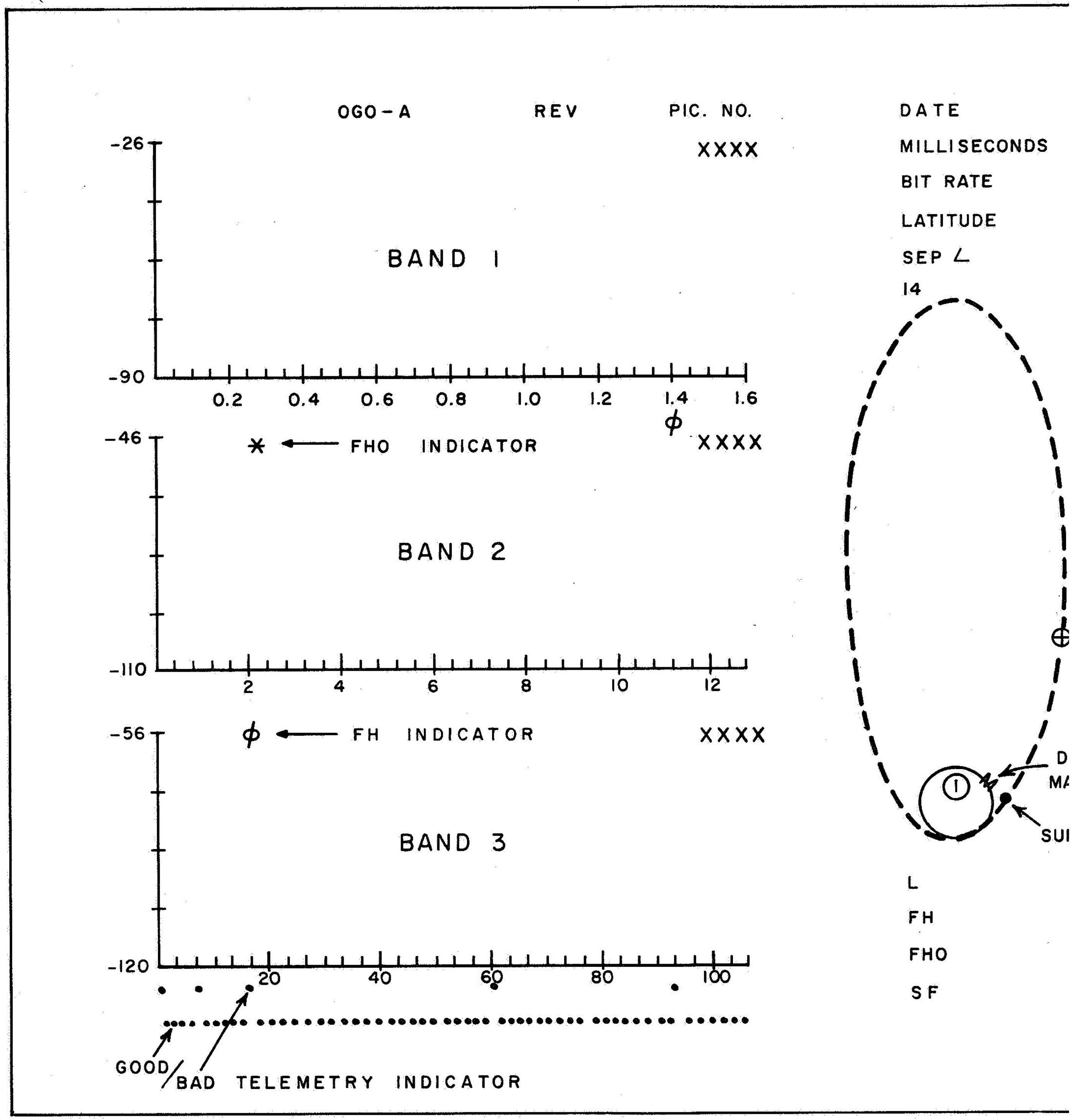
The system is now in the Scale Mode (see Sec. 5.2.6.4).

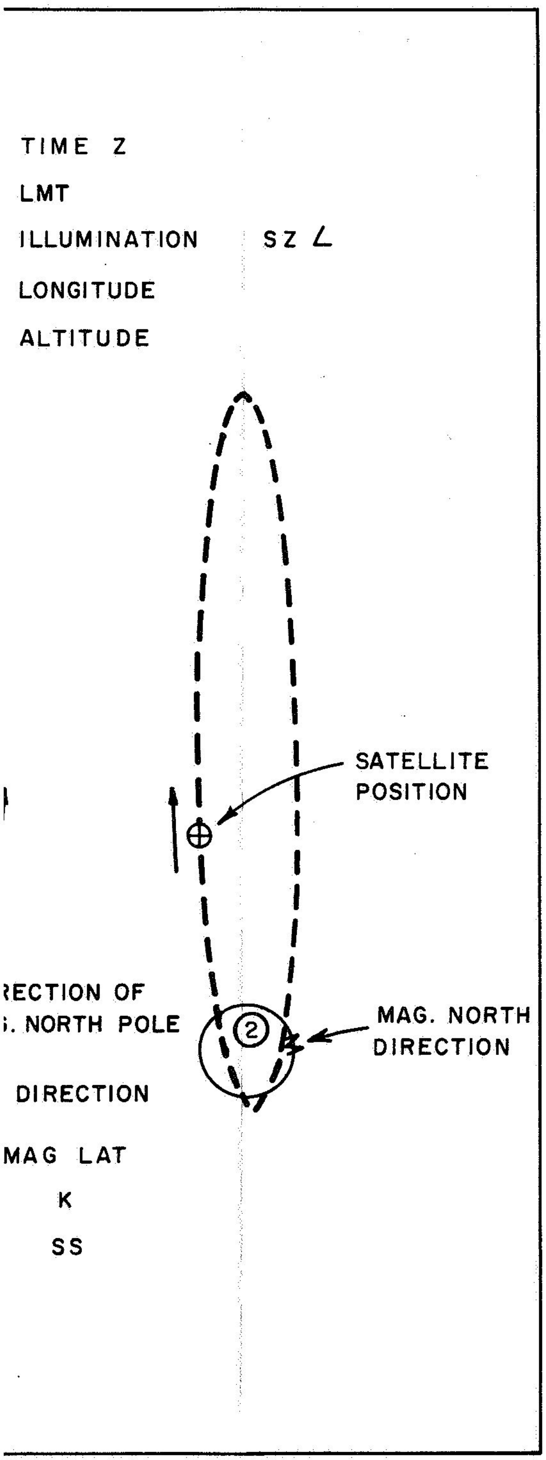
5.2.6.2 Film Mode Operation

The Film Mode is entered from either the Scale or the Scan Mode by depressing the F key on the typewriter. The camera will be started and the film exposed until a stop is either signaled by the operator--by depressing the S key on the typewriter--or by the computer, because of a bad frame, parity, end of file, or end of tape. At the stop, the system is left in the mode determined by the particular condition:

Action	Mode
Manual stop	Scan
Bad frame	Scan
Parity on tape	Scan
End of file	Computer halt
End of tape	Computer halt .

When the Film Mode is entered from the Scan Mode, the first frame exposed will be the one currently visible in the Scan Mode.


OGO-A
REV
PIC. NO.
XXXX
DATE
MILLISECONDS
BIT RATE
LATITUDE
SEP ∠
14
-26
-90
BAND 1
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
φ
-46
✳ FHO INDICATOR
XXXX
BAND 2
-110
2
4
6
8
10
12
-56
φ FH INDICATOR
XXXX
BAND 3
-120
20
40
60
80
100
GOOD/BAD TELEMETRY INDICATOR
L
FH
FHO
SF



OGO-A	SATELLITE IDENTIFICATION
REV	REVOLUTION
PIC. NO.	FRAME NUMBER
DATE	MONTH/DAY/YEAR
TIME	UT2 TIME
MILLISECONDS	.XXX SECONDS
LMT	LOCAL MEAN TIME
XXXX	FREQUENCY IN FIXED-FREQUENCY MODE
BIT RATE	1, 8, OR 64 KB/S (LBR, MBR, HBR)
ILLUMINATION	SUN OR ECLIPSE (ECL)
SZ	SOLAR ZENITH ANGLE
LATITUDE	LATITUDE °N, S (N+, S-)
LONGITUDE	LONGITUDE °E, W (E+, W-)
SEP ∠	SUN-EARTH-PROBE ANGLE
ALTITUDE	ALTITUDE ABOVE EARTH SURFACE IN KILOMETERS
14	INDICATES EXP. 14 ON (DELETED FOR EXP. 14 OFF)
L	Mc ILLWAIN L PARAMETER
MAG LAT	MAGNETIC LATITUDE °N, S (N+, S-)
FH	GYROFREQUENCY
FHO	MINIMUM GYROFREQUENCY FIELD LINE
K	3-HOUR MAGNETIC INDEX (FREDERICKSBURG, MD.)
SS	SUNSPOT NUMBER
SF	SOLAR FLARE

(1) SATELLITE ORBIT — GEOGRAPHIC NORTH-POLAR PROJECTION

(2) SATELLITE ORBIT — SIDE VIEW

NOTE 1: ORDINATE SCALE IS MAGNETIC FIELD INTENSITY IN DECIBELS REFERENCED TO 1 GAMMA rms. ABSCISSA SCALE IS FREQUENCY IN kHz.

NOTE 2: WHEN EXPERIMENT A-17 IS CHANGED FROM SWEEP-TO FIXED-FREQUENCY MODE, THE FREQUENCY SCALES ARE REPLACED BY TIME SCALES WHICH CORRESPOND TO THE LBR, MBR, OR HBR SAMPLING RATE. IN THE FIXED-FREQUENCY CASE, THE XXXX SHOWS THE FREQUENCY USED IN EACH BAND.

D-4007-51R

FIG. 5.12 EXPLANATION OF 16-mm CINE FRAME

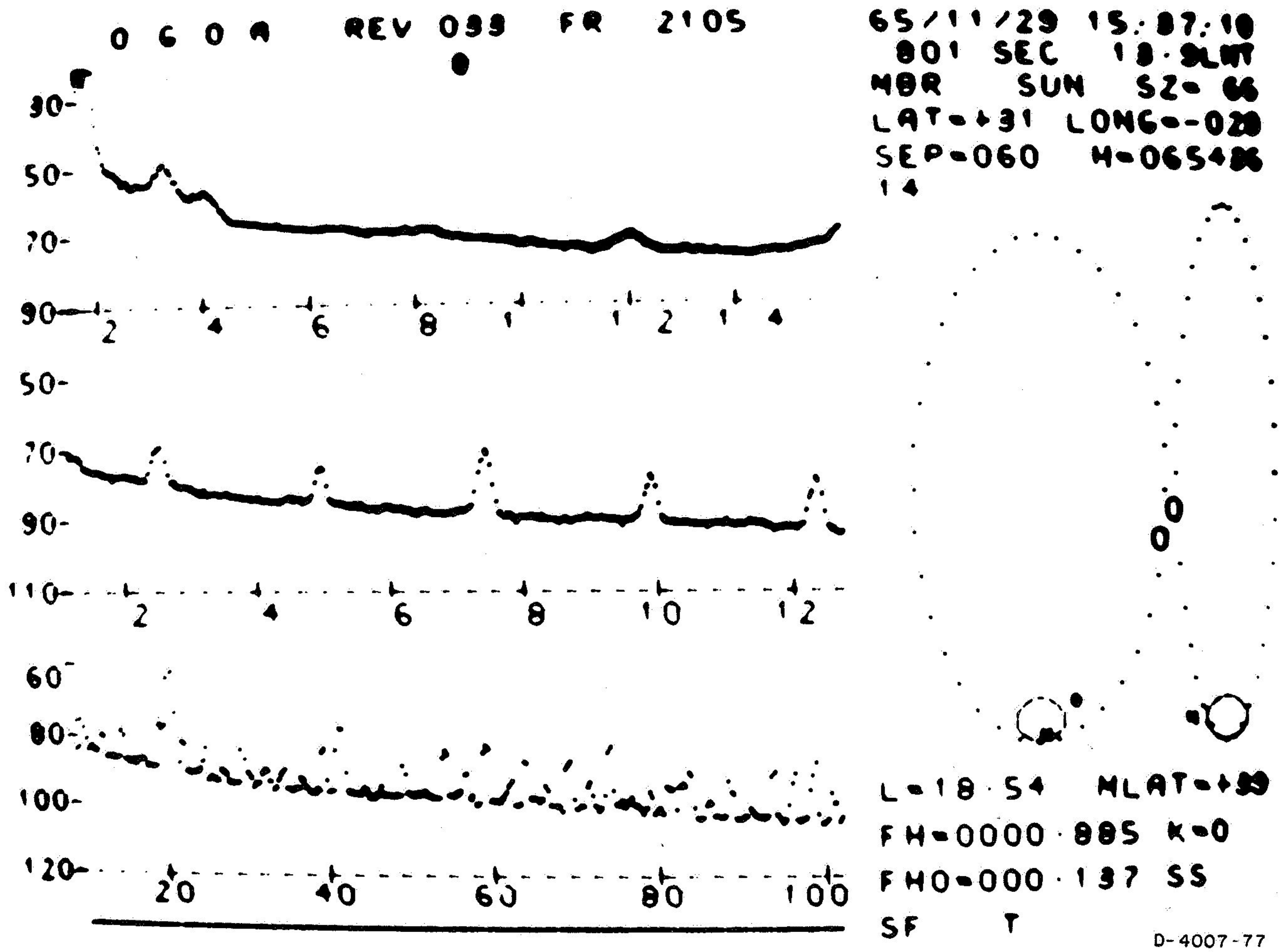


FIG. 5.13 EXAMPLE OF A 16-mm CINE FRAME

5.2.6.3 Scan Mode Operation

The Scan Mode can be entered from either the Scale or the Film Mode by the following conditions:

Current Mode	Condition
Scale	Type in: SC
Film	Type in: SC
Film	Bad frame
Film	Parity on tape

The Scan Mode provides a means of examining the tape information without filming it. Action is controlled by typewriter input according to the following scheme:

Typewriter Input	Action
Axxxx space, where the xxxx represents a decimal number of one to four digits (max. 2047)	Advance xxxx frames, showing frames on the display without filming them. After xxxx frames, stop tape and show current frame.
Rxxxx space	Same as above, except that the scan is backward along the tape.
S during a forward or backward scan (above)	Stop the scan. Remain in Scan Mode.
F	Enter Film Mode.

During all actions in the Scan Mode, "bad frame" indications are not given. If "end of file" is met in Scan Mode, the computer will so indicate and will then halt. To restart, rewind tape, set p = 100, and run, whereupon the system is in the Scale Mode and can be put in the Scan Mode by typing in SC on the typewriter.

5.2.6.4 Scale Mode Operation

At the start of a run, it is possible to change the scale marks and values of the horizontal axes of the three graphs in both the sweep and the static mode. All changes are specified on the typewriter. Each graph displays 256 points, and the position of each scale mark is specified with respect to the "graph point number" in the range 0 to 255. For example (see below for details), the typed-in command "T space 127 space 32.7 carriage return" will cause a mark to be made on the horizontal axis of the top graph (the "T" above), half-way along the axis (the "127" above), and below the mark the digits "32.7" will be displayed.

The following commands are typed into the computer:

Command	Action in 160-A
SW	Clear the three horizontal axes in the sweep mode. The scale specifications refer to sweep mode.
ST	Same as above except for fixed-frequency mode.
TspaceXYZspaceABCDcarriage return	A scale mark is placed at the XYZ (0-to-255) point of the axis of the top graph, and the digits ABCD are placed below it. XYZ must be made up of three digits (0-9), i.e., the number 7 is input as 007. Exactly four characters must be in the group ABCD, spaces being allowed. The decimal point is input as a semi-colon on the typewriter. Any non-displayable input (e.g., carriage return, case shift) causes a space.
MspaceXYZspaceABCDcarriage return	Same as above, but scales are marked in middle graph.
BspaceXYZspaceABCDcarriage return	Same as above, but scales are marked in bottom graph.
F	Enter Film Mode.
SC	Enter Scan Mode.

C — Punch out a bioctal copy of the program. After punching out, the computer will halt; the paper tape should be placed in the reader and the computer restarted, whereupon the tape is checked for correct punching. (If correct, the program returns to the Scale Mode; if incorrect, REPUNCH will be typed out before the Scale Mode is entered. The command C should be repeated. If a second failure occurs, call maintenance engineer.)

In the fixed-frequency mode, the top, middle, and bottom frequency scales are replaced by a time scale that depends on the bit rate. All scale figures in the fixed-frequency mode are displayed below the bottom horizontal axis; the remaining axes have tick marks corresponding to the scale marked on the bottom graph.

During scaling, the particular scale entries are displayed as soon as they are entered.

All typing that does not correspond to one of the above commands causes no action, and a carriage return is sent to the typewriter by the 160-A with the exception that if XY and Z are not numeric, the scale marking is placed at indeterminate positions.

5.2.6.5 Error Conditions

Three error conditions are described below.

(1) End of Tape

The typewriter types END OF TAPE if the end-of-tape warning mark is detected. This should not occur and represents either a data tape that has not been closed out by two END OF FILE marks or an error in operation in attempting to film data after all data on a tape have been exhausted.

(2) Bad Frame

With a type-out BAD FRAME on the typewriter, the camera automatically stops. This stop may be caused by either a solid parity error on the data tape or an excessive number of telemetry errors from the satellite. In either case, the frame displayed is the one in error. The system is left in the Scan Mode.

(3) End of Film

The END OF FILM detector on the camera automatically stops it. The computer idles. The camera interface should be switched off, and new film should be loaded into the camera. When the camera has been loaded and the first few feet of film have been run, the computer should be taken out of run, the interface should be switched on, and the clear button should be depressed. The computer should be put back into run position and the camera manually started. The computer will automatically continue to read tape and display data.

5.2.7 Camera Recording System

The portrayal of successive frames of satellite data on motion picture film required the use of a CDC 160-A computer, a cathode-ray display unit, and a motion picture camera. See Fig. 5.14.

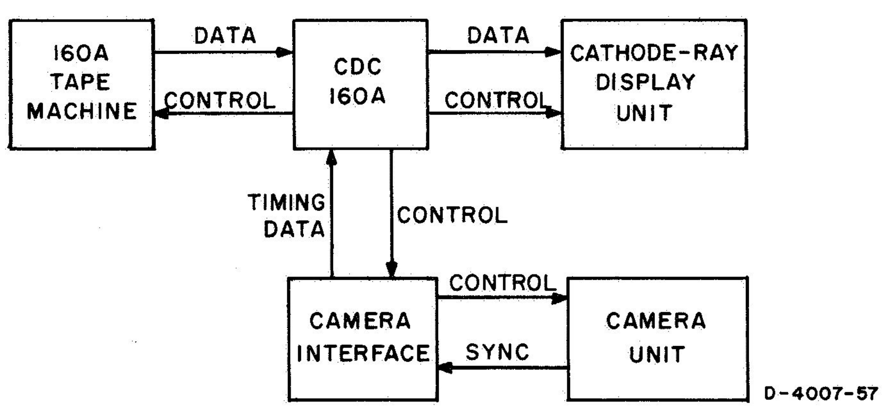


FIG. 5.14 BLOCK DIAGRAM OF FILM RECORDING SYSTEM

An interface system was constructed to perform the various logic functions necessary to enable the computer to control the camera. These functions included the selection of the camera equipment by the computer, starting and stopping the film, and synchronization of the display with the camera shutter.

A program was written for the 160-A to enable the equipment to work as a system. Data read from the display tape are checked and stored in one memory bank. If they check correctly, the camera is then signaled to start film motion. When the shutter is open, a go-ahead signal is sent back to the 160-A from the interface system, and the data are presented on the CRT. The display is completed before the camera shutter closes. During the display period, a new frame of data is being read from tape, processed, checked, and stored in a second memory bank. This second frame remains in memory until the film is transported and the shutter is again opened. It is then displayed while a new frame of data is being read and processed.

This method has allowed the processing of data from tape to film at about ten frames per second. In free-run mode, the camera speed is adjusted to be just slightly slower than the time for processing each frame of data. The camera speed is, therefore, the synchronizing element for the system.

In the event that the 160-A senses a discrepancy in a frame of data, the camera is stopped by the interface system, and the display unit presents that frame. The operator, alerted to error in the data, must make a decision to record or reject the frame on the basis of the presentation on the display.

The camera system is composed of the following:

(1) A Kodak 16-mm motion picutre camera with a C-mount f1.9 lens

(2) A 400-foot film magazine

(3) A film hood, with dichroic mirror

(4) A variable speed control motor which allows the camera to operate at rates of 7.5, 10, and 20 frames per second in cine mode, or up to 5 frames per second in pulsed mode

(5) An electronic logic package which synchronizes the camera timing with respect to the computer-to-camera interface.

(6) A dc ammeter which indicates the intensity of the CRT display output.

The camera system is shown in Fig. 5.15. This photograph shows the 16-mm camera, the film hood with the dichroic mirror mounted

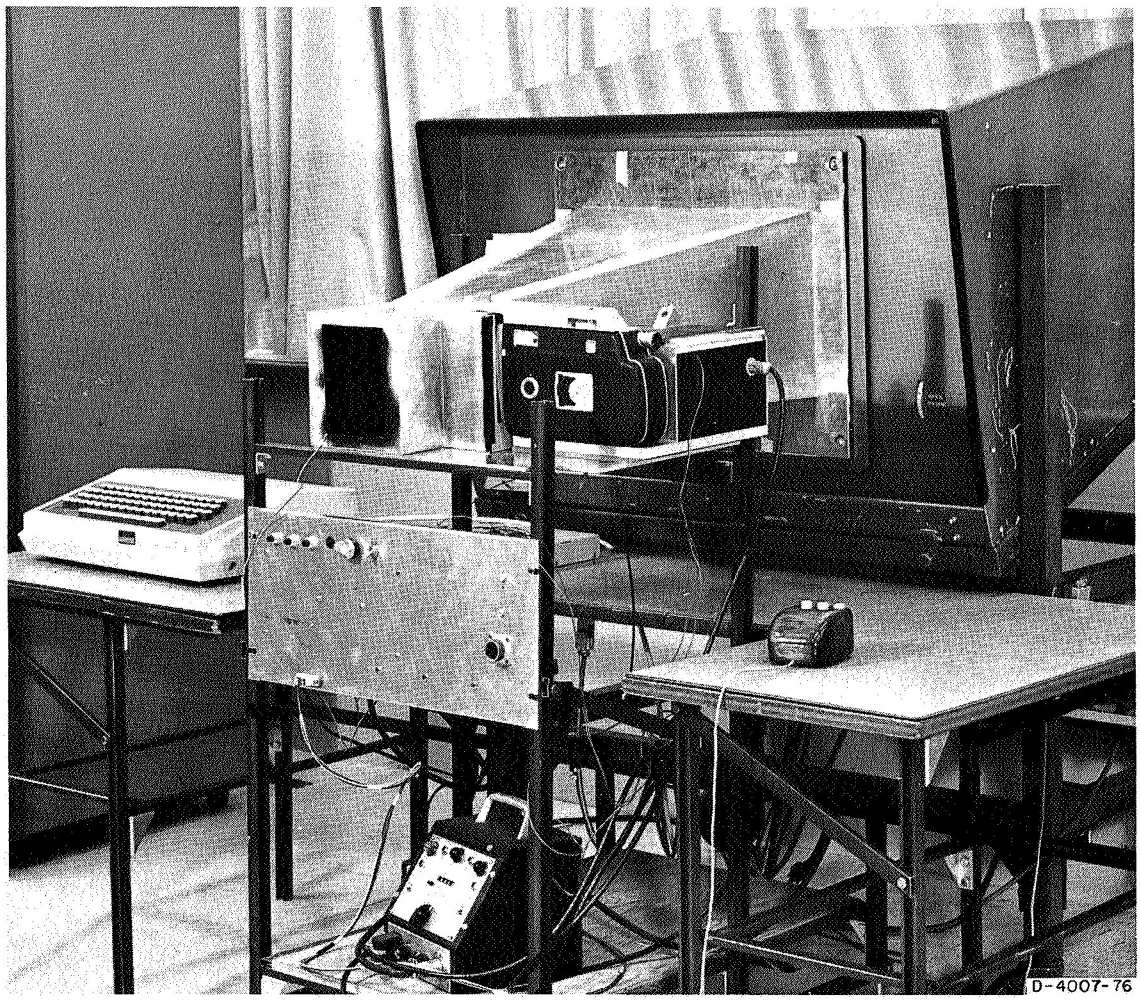


FIG. 5.15 16-mm CAMERA AND DISPLAY

inside the viewing aperture, the speed-control box, and the mounting plate and switches for the electronics logic package. The camera and interface logic hardware are cart mounted. The camera is mounted at a 45° angle with respect to the dichroic mirror and parallel to the tube face. This configuration permits viewing of data being displayed on line while they are being photographed. As shown in the figure, the film hood bolts directly to the CRT, thus providing for uniformity in film exposure, frame size, and intensity. The display films are 400-foot rolls of 16-mm double-sprocketed Kodak Linagraph Ortho safety film.

Appendix

OGO SATELLITE AND SU/SRI EXPERIMENT CHARACTERISTICS

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Appendix

OGO SATELLITE AND SU/SRI EXPERIMENT CHARACTERISTICS *

NAME		LAUNCH DATE	ORBIT PERIOD (hr)	PERIGEE (km)		APOGEE (km)		INCLINATION ANGLE (degrees)	SPIN PERIOD (s)	TOTAL EXPERIMENTS ABOARD	EXPERIMENT NUMBER (and alternate)	DATA RATES (kb/s)	SWEEP RECEIVER PERIODS (s)	SRI FILMS		SRI PROJECT NO.	
Design Order	Launch Order (Alternate)			Initial	Present	Initial	Present							Data Orbits	Data Frames	Instrument Construction	Data Analysis
OGO-A (S-49)	OGO-I (EOGO-I)	7 Sept. 1964	64	465	4,900	149,000	145,000	31.1	12	20	A-17 (4917)	64 8 1	2.3 18.4 147.2	99	200,000	4007	4007
OGO-C (S-50)	OGO-II (POGO-I)	14 Oct. 1965	1.75	427	430	1,526	1,500	87.5	480	20	C-02 (5002)	64 16 4	4.6 18.4 73.7	2,300	80,000	4424	5631
OGO-B	OGO-III (EOGO-II)	7 June 1966	48.4	255	468	122,181	122,000	30.9	96	20	B-17	64 8 1	2.3 18.4 147.2	--	--	4007	5915
OGO-D	--	Scheduled third quarter 1967	--	Planned 360		Planned 900		Planned 86.0	Planned Stable	20	D-02	64 16 4	4.6 18.4 73.7	--	--	4424 6116 6155	--
OGO-F†	--	Scheduled fourth quarter 1968	--	--	--	--	--	--	--	26	F-24	64 16 8	--	--	--	6045	--

* As of May 1967.

† SU/SRI have no experiment aboard OGO-E.

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